MACKENZIE VALLEY PIPELINE INQUIRY

IN THE MATTER OF AN APPLICATION BY CANADIAN ARCTIC GAS PIPELINE LIMITED FOR A RIGHT-OF-WAY THAT MIGHT BE GRANTED ACROSS CROWN LANDS WITHIN THE YUKON TERRITORY AND THE NORTHWEST TERRITORIES FOR THE PURPOSE OF THE PROPOSED MACKENZIE VALLEY PIPELINE

and

IN THE MATTER OF THE SOCIAL, ENVIRONMENTAL AND ECONOMIC IMPACT REGIONALLY OF THE CONSTRUCTION, OPERATION AND SUBSEQUENT ABANDONMENT OF THE ABOVE PROPOSED PIPELINE

(Before the Honourable Mr.Justice Berger Commissioner)

Yellowknife, N.W.T.

March 18, 1975.

PROCEEDINGS AT INQUIRY

VOLUME XX

ALLWEST REPORTING LTD.,
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APPEARANCES:

Mr. Ian G. Scott, Q.C. Mr. Stephen T. Goudge, Mr. Alick Ryder and Mr. Ian Roland	for Mackenzie Valley Pipeline Enquiry;
Mr. Pierre Genest, Q.C. Mr. Jack Marshall, Mr. Darryl Carter, and Mr. John Steeves	for Canadian Arctic Gas Pipeline Limited;
Mr. Reginald Gibbs Q.C. Mr. Alan Hollingworth	for Foothills Pipelines Ltd.;
Mr. Russell Anthony, Prof. Alastair Lucas & Dr. Andrew Thompson	for Canadian Arctic Resources Committee;
Mr. Glen W. Bell and Mr. Gerry Sutton	for Northwest Territories Indian Brotherhood and Metis Association of the Northwest Territories;
Mr. John U. Bayly	for Inuit Tapirisat of Canada and the Committee for Original Peoples' Entitlement;
Mr. Ron Veale and Mr. Allan Luke	for Yukon Native Brotherhood;
Mr. Carson H. Templeton	for Environment Protection Board;
Mr. David Reesor	for Northwest Territories Association of Municipalities
Mr. Murray Sigler	Northwest Territories Chamber of Commerce

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ERRATUM

For PAG should read PAAG

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(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

MR. GENEST : Mr. Commissioner, may I proceed with the evidence in chief of this panel?

MR. SCOTT: I think Mr. Anthony had something to raise first.

MR. ANTHONY: I would like, if I may, to follow up something with Mr. Genest. During the cross-examination of Panel 1, Arctic Gas gave an undertaking that the transcripts of the April, 1973 meeting would be made available to this Inquiry, and yesterday in the evidence before us Dr. Clark once again referred to this meeting in April. I was wondering if my friend would be able to have these transcripts available in time that we may cross-examine this panel with respect to that very important meeting?

MR. GENEST : I hope to have these here tomorrow. We don't trust anything to the mails any more and I have a party coming up on the plane tomorrow and I should have them for my friend at that time.

MR. ANTHONY: I'm wondering if when that party arrives you could deal with one other matter, and that was again last week during the questioning with respect to Panel 1, Mr. Genest, on behalf of Arctic Gas, advised that they had received certain environmental information with respect to the cross-delta route, and it was this environmental

input that allowed them to reconsider the question and they will be filing their cross-delta information at some time, but I think it would be of assistance to this Inquiry if this information, which they now have, could be made available at an early date prior to the actual filing of the cross-delta information. I wonder if my friend could perhaps obtain that information at an early date also?

MR. GENEST: I'll do my best, sir. The reason that's sort of a vague answer, Mr. Anthony, perhaps tomorrow morning I can be more definite. I know that we are hoping to get the alignment sheets by the end of this week, and somebody is somewhere at work collecting the reports and I should have them about -- let me tell my friend definitely tomorrow morning, if he will give me one more day on it.

MR. ANTHONY: Perhaps to make this clear, I'm not at this stage requesting that the full cross-delta information including the alignment sheets be made available. I'm really directing my attention to reports which, according to Arctic Gas now, exist, basically the environmental reports.

MR. GENEST: I understand, sir.

THE COMMISSIONER: All right, Mr. Genest, carry on.

MR. GENEST: Thank you, sir.

JOHN IVOR CLARK,
GARRY WOOD HOLLINGSHEAD,
EDWARD CHARLES McROBERTS,
WILLIAM ALEXANDER SLUSARCHUK,
NORBERT REUBEN MORGENSTERN
RICHARD H. COOPER,
R.H. HARDY,
GUY LESLIE WILLIAMS, resumed:

DIRECT EXAMINATION BY MR. GENEST (CONTINUED):

Q I should like to move on now, Dr. Clark, with that section of the evidence of this panel which deals with the concerns of the Pipeline Assessment Group which were expressed in their report which has been filed before this Inquiry as Exhibit 69, and perhaps it might be useful if I recalled at this stage that the applicant was sent a number of requests for additional information. The responses are filed as Exhibit No. 70, and I understand were received or at least that when the Mackenzie Valley Pipeline Assessment was produced the answers to the requests had not been fully taken into account. I'd like to ask you, sir, to deal with these concerns as they apply to the geotechnical area. I understand that a number of these were expressed in their request for supplementary information. Some of these were dealt with in your responses, and there are some concerns that appear throughout Exhibit 69 which is the assessment itself. Let me ask you first generally, were these responses within the geotechnical area prepared by members or participated in by members of your panel?

A Yes sir, both members of our panel as well as other staff members of N.E.S.

as well as others.

Q Now could you identify the sections of the Assessment Report which are predominantly of a geotechnical nature?

A Yes sir. The sections of the report which relate to Phase 1 of these hearings which are predominantly of a geotechnical nature, and which have not been covered by Panel 1, are all within chapter 8, "The physical environment and engineering." Some of these sections within this chapter will be dealt with in Phase 2 of these hearings. Now those sections which this panel will deal with are 8.1 chilled pipeline, page 169; 8.2, buried pipeline rationale, page 179; 8.5, slope stability and erosion susceptibility, page 191; 8.7, river crossings, page 206; 8.8. pipeline impact in valleys, page 215; 8.9, drainage and erosion control, page 224; 8.10, springs and icings, page 229.

Many of these concerns raised in the above sections of the report have been addressed in previous responses to the PAG questions. The questions which required significant geotechnical input are questions 16, 17, 18, 19, 20, 21, 23, 24, 26, 28, 29, 30, 35, 36, 37, 38, 39, 41, 42, 55 and 56.

Now in the following comments we will provide information -- additional information -- where possible, or we'll address concerns not contained in the original PAG request for supplementary information.

Now the PAG Report does outline several conerns, but they can be basically grouped into four areas which in various forms are expressed throughout the report. These are No. 1, drainage and erosion control; 2, the effect of freezing previously unfrozen ground; 3, river crossings; and No. 4, slope stability.

Q These four topics that you have named, am I right in assuming that they encompass really the main headings of geotechnical concern in building a Northern Pipeline?

A That is our assessment, sir, that they do.

Q Right, and you are going to be addressing each of these in detail?

A Yes, sir.

Q Right. Please proceed.

A Well, we have listed several reports in Appendix "C" to this testimony which pertain to these subjects and since submission of the testimonies, others have become available and those additional reports which are now available will be provided to the participants in the usual manner. Since these hearings started on the technical aspects, Mr. Genest, we have provided you with five additional reports. Three of these you named last Tuesday at the opening of the technical hearings and I would like to point out that those particular three reports were completed on the previous Friday and Saturday. They were bound on the Saturday and Sunday, they were on the aircraft with us on Monday and were on your table on Tuesday. The two reports which you submitted yesterday actually preceded those three and they were in the usual way put in the mail to be available here and when I found out for various reasons which have been mentioned several times that they did not arrive, I immediately obtained copies and on this past weekend

to -- in order that participants could have access to them as soon as possible and those were the two that you mentioned yesterday.

Q CAn we move on now, sir, to the particular concerns.

A Yes, sir, I would like to start with the concerne expressed in Section 8.1 which is entitled "Chilled Pipeline", covered by pages 169 to 173.

Now, some of the concerns discussed by PAG in this section relate to frost heaving around the chilled pipe.

A) the PAg concern, frost heaving around pipe buried in permafrost. PAG states on page 170 that"although the rate of water migration in frozen soil is low, it could produce significant heave over the long operating life of the pipeline"and to make this clear, what we are talking about now is frost heave in frozen soils. Soils which, when the pipeline is placed in the ground are frozen and when it goes into operation they are frozen. Our response to this --

Q Well, perhaps before we get into the response so I am sure that we all understand I note that the PAG have, and I think you agree, I think that we heard some overview evidence on this that there is a tendency for water to migrate.

A There is a tendency for water to migrate in frozen soils along the lines of the thermal gradient.

Q What causes that? What is that?

A It is the thermal gradient.

Q It is like a slope? Only it is thermal?

A Yes, a thermal slope, water will run --

Q From where to where?

A It runs from the warmer to the colder.

Q So that a cold front will attract water in the vicinity?

A From a warmer area.

Q From a warmer area.

A Yes, sir.

Q And when it gets to the cold front it will freeze and will attract more water?

A Portions of it will freeze, right.

Q Right.

A Now, from the studies that we have undertaken for the applicant it is our view that water migration in permafrost due to operating the pipeline at below freezing temperatures would not produce significant heave during the life of the pipeline. The reasons for this are, number one, the thermal gradients are largest adjacent to the pipe, but even there the values are only a few degrees Farenheit per foot. These gradients rapidly become

smaller further away from the pipe tending towards the value of the geothermal gradient which is about 2 degrees Farenheit per 100 feet.

Number two, the hydraulic conductivity of permafrost is very low. It ranges from approximately $1X10^{-9}$ to 10^{-15} centimeters per second and is lowest in the permafrost around the cold pipe where the highest thermal gradients exist. In addition, if ice lenses do develop, this will tend to further reduce the local hydraulic conductivity.

Number three, the unfrozen water content is lowest in the permafrost around the cold pipe where the highest thermal gradients exist. Even when some small amounts of moisture are redistributed from warmer to colder areas within permafrost and form ice lenses, this does not mean that heaving still will be equal to the amount of moisture moved.

THE COMMISSIONER: Excuse me a moment,Dr. Clark. Everyone seems to be reading this. Is that so or --

MR. GENEST: Yes, sir, our communications seemed to have broken down. I handed copies of this to Mr. Waddell.

THE COMMISSIONER: Well, without going into the whole thing, is there an extra copy, that is the --

MR. GENEST: I appologise, sir, I should have made sure that you --

MR. SCOTT: I think that it is probably our fault. I will plead guilty to that.

MR. GENEST: That clears you for five weeks. On page 3 of that, sir.

A The top of page 4.

Q Or top of page 4 -- that was a response to my friend's --

THE COMMISSIONER: To the Assessment Group's report --

MR. GENEST: To the Assessment Group's report and that provides an outline of the testimony of this group.

And I might add, sir, that we have also notified the -- my friends at the -- a number of the statements contained in this outline of evidence will be illustrated by slide presentations. -- And we will get to these in due course.

THE COMMISSIONER: At appropriate points.

MR. GENEST: At appropriate points.

Dr. Clark, so that we can just get all together, you have given three reasons, at page three of this summary, why it is your view that water migration due to operating a pipeline at below freezing temperatures will not produce significant heave and the first was that the thermal gradients are largest adjacent to the pipe, but even there the values are only a few degrees Farenheit per foot.

A Yes, sir.

Q And then you make the statement that the gradients rapidly become smaller

further away from the pipe tending towards the value of the geothermal gradient which is about 2°F. per 100 feet.

A Yes, sir.

Q I am sure that is clear to scientists, but could you try and explain that to my non-scientific mind?

A Well, this is one of the objectives of putting on a slide presentation and discussion where we will try and illustrate the features that we discuss here, which I apologize, it is not possible really to answer a technical question in a non-technical manner. We have attempted to make these as comprehensible as possible, sir. And I believe that these presententations that we will see with slides will make a number of these points quite clearly --

The second point was of course that the hydralic conductivity is very, very low in these frozen soils and the third, where I was discussing the unfrozen water content, the unfrozen water content is coldest, is lowest in the area of the coldest temperatures which is nearest to the pipe and --

Q We are dealing here of course with a concern about frozen ground --

A Frozen ground.

Q Frozen ground.

A Frozen ground is I am sure --

Q That is frost -- frozen ground --

A Yes, but not all the water in frozen ground is frozen --

Q Right--

A And it is the movement of that water that we are discussing --

Q Right.

A Because that is where the source of frost heave would come from.

Now, I had just mentioned that even if this water does move and form ice lenses, it does not mean that heaving would be equal to the amount of moisture moved, because there is some compensation for that. The zone from which the moisture moved, it could consolidate because of the suction pressures that are required to locally reduce the water content, so that the net heave then is generally limited to only 9% change in volume of the relocated water upon freezing.

Now, because of these factors, the amount of heave due to thermal gradient surrounding the pipe in permafrost is not expected to exceed about an inch or two over the life of the pipeline. Now, this is not considered to be a significant problem. It should also be noted that because of similar thermal gradients around the pipe over say, 100 to 200 foot lengths, that there would be little tendency for this total heave to contribute to differential heave along the pipe. As I mentioned yesterday, it is the differential heave that imparts stress to the pipe.

The next PAG concern is related to frost heaving around pipe buried in unfrozen ground. PAG states on page 170 that "the potential magnitude and rate of frost heave under chilling conditions is poorly understood. PAG further states, page 171,"no simple, reliable and economically feasible measures are available for eliminating or reducing potential problems of Frost heaving associated with the buried chilled line."

At the same time, PAG did recognize that while it was reviewing the application, a major study on frost heaving related to operating a pipeline at below freezing temperatures in unfrozen, frost-susceptible soil was being carried out for the applicant.

Q Now that major study has been completed, has it, sir?

A We have produced the results derived from that study to date. It is an on-going study. All facilities are still operative.

THE COMMISSIONER: That is the Calgary study?

A Yes sir, and Dr. Slusarchuk will be describing this in some greater detail.

From the results of our major study on frost heave as related to the pipeline, it is clear, at least from an engineering point of view, that the potential magnitude in rate of frost heaving can be reasonably predicted by rational analysis. The study has shown that an increase in overburden pressure can significantly reduce the rate of heave. We intend to take advantage of this fact by burying the pipe deeper, and where necessary, by surcharging the ground surface to increase the load on the frost front to reduce the rate of heave.

Other means of designing to control frost heave problems consist of methods such as replacing the frost-susceptible soil with non-frost-susceptible soil, or reducing the heat flow

out of the pipe by insulation. For special situations, such as at river crossings, the concept of dual pipelines might be used to advantage by alternating flow. It is our position, therefore, that the frost heaving of the pipeline is a minimal to rational analysis and that reasonable engineering designs for frost heaving are available. There are two components of total frost heave:

(1) is due to the natural expansion of the water in the pores of the soil that freezes in place.

(2) the other component is due to water migrating into the freezing soil from the surrounding unfrozen ground and forming segregated lenses or layers of ice.

There are two general guidelines that we follow which govern the amount of acceptable heave:

(1) relates to total heave, and

(2) the other to differential heave.

Our guideline for total heave is that the pipe should not heave such that the top of the pipe rises to a level of about one foot below the original ground surface. I should make clear here this is not a case of the pipe rising through the soil, it's a case of the pipe contained in a mass of soil rising with the soil.

Q That's, if I may oversimplify that, total heave would be the total pipeline or a very large section --

A It would be a large section.

Q -- rising all at once.

A Across the right-of-way.

Q Right.

A Gradually slowly coming up at a decreasing rate.

Q And differential heave is when you have one section that stays still, if I can call it that, and another section beside it that is heaved.

A That's right.

Q Producing a --

A Producing a relative movement. Both might be moving, but one might be moving faster, that is what we refer to as differential heave.

Now the criteria for total heave is to ensure that the pipe doesn't block cross-drainage or become exposed. Now with respect to differential heave, our guideline is that the pipe should not heave differentially along its length such that the serviceable radius of curvature of the pipe is exceeded. Now by way of definition, the radius of curvature of the pipe is defined as the reciprocal of the radius of the arc of the curve through which the pipe is bent. The serviceable radius of curvature as used here is the allowable radius of curvature to which the pipe can be bent as determined by the

mechanical stress analysis group. This work is carried out, the mechanical stress analysis in Northern Engineering.

Q Now that's a guideline that's given to you.

A This is a guideline that has evolved from our studies and our stress analysis work and so on. Now as an example, in general, the amount of differential heave over pipeline lengths of 100 to 150 feet should not exceed about 2 1/2 to four feet. Differential heave will be some percentage of total heave up to a maximum amount of 100%, which is virtually an impossible situation for 100% to be differential. But it is reasonable to assume that the actual percentage will be less than this value, possibly of the order of 50%. However, establishing this value, the relationship between differential and total heave, forms part of the engineering work that is currently under way for use in final design.

Q Now can I stop you there again, Dr. Clark? You say that in general the amount of differential heave over pipeline lengths of 100 to 150 feet should not exceed about 2 1/2 to 4 feet.

Below four feet, the pipeline metal, if I can use layman's word, is so designed that it can withstand this kind of movement or action.

A Yes. This would keep it

within the limits established for the serviceable radius of curvature.

Now a specific concern along the route where differential heave is to be considered is those points where the pipeline crosses boundaries between permafrost and adjacent unfrozen areas that consist of frost-susceptible soil. We have developed techniques to analyze this situation in detail, and analysis have been done by hand methods.

Q Could I ask you what these techniques are, sir?

A They are analysis including the pipe soil inter-action, the amount of heave that occurs in the adjacent soil which is unfrozen, to -- compared to what's happening in the frozen later, what the resistance at the bottom of the pipe would be For instance, if the soil is securely held in a frozen soil adjacent to an unfrozen soil, the force required to lift that pipe into a sharp curve far exceeds the capability of the soil to form ice lenses. Dr. Slusachuk will be illustrating the concept of shut-off pressure so that these very high forces cannot develop in a localized area because the water will in fact be expelled, or the rate of growth will be inhibited to the point where there would not be a sharp change in curvature.

There is now a computer program that's -- we have in house and has been finalized for use in final design.

Now to illustrate some of these points, sir, I would like to call upon Dr. Slusarchuk to present us with some slides and a more detailed discussion of some of these aspects.

Q Will you proceed, Dr. Slusarchuk? Before you start the illustration, it might be useful to recall as I understand it the frost heave study was under your direction. Am I correct?

WITNESS SLUSARCHUK: Yes, that's correct, sir.

Q And you really specialized in those aspects of geotechnical engineering.

A Yes sir, I have certainly become more specialized in the last couple of years in this area.

Q Fine.

A I'm not really sure if I should have something around my neck or not, because I'm going to have to go over here, and then over to here. Am I going to be able to be --

THE REPORTER: That mike doesn't work as a P.A.

A It is my purpose to talk about frost heaving with regard to buried pipelines which are operated at below freezing temperature in frost-susceptible soil. By "frost-susceptible soil" I mean a soil in which segregated lenses of ice will develop during freezing by drawing water into the freezing zone.

from the surrounding unfrozen ground and thereby causing the soil and the pipe to heave. Specifically, I shall discuss the major study on frost heave that we have undertaken during the past 1 1/2 to 2 years by describing our full-scale field test facility, our laboratory buried pipe model tests, and our laboratory frost-heave tests on 4-inch diameter, undisturbed soil samples. From these samples we have experimentally determined the frost-heaving characteristics of soil from the field test-site and for soils from sites located along the pipeline route.

I shall present some of the results of these studies and show how these results can be used to advantange when designing for frost heave of a chilled pipeline buried in unfrozen ground. The central thesis of our design concept is based on the simple fact that the rate of heave of a freezing frost-susceptible soil is significantly reduced by having only nominal increases in loads acting on the freezing front. By "nominal loads" I mean loads that are similar to those that would exist or could be caused to exist on the freezing front around our chilled pipeline. Later I shall present specific values for a range of loads to which I now refer. May I have the first slide, please?

This shows the approximate position of our pipeline. This is the southern limit of continuous permafrost zone, and the southern limit of the discontinuous permafrost zone.

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The potential for frost heave exists wherever the ground is frozen and the pipeline is operated at temperatures below 32 degrees Fahrenheit. Our pipeline is operated at temperatures below 32 degrees Fahrenheit to an area of approximately down to the 60th Parallel. In the continuous permafrost zone, there is only minor areas of unfrozen ground, such as under river crossings that we must cross.

In the discontinuous zone, however, there is unfrozen ground not only under the river crossing, but under the ordinary ground that simply is not frozen naturally.

To evaluate -- it was to evaluate the potential for frost heave along this route that we undertook our major frost heave study.

CAn I have the next slide, please.

I should like to discuss our studies by first talking about the field test site that we have at Calgary. This shows the site plan of the Calgary test facility. We have an equipment building which houses our refrigeration which keeps our air circulating at approximately 10°F through our four buried sections, one located there, one here, another here and the final one here. The control section -- this is a four foot diameter pipe, 40' in length and the top of the pipe is 2 1/2 feet beneath the nominal ground surface.

In the deep burial section, it is buried an extra three feet deeper than the control section in order to obtain information on the effect of deeper burial on the rate of heave of our frozen zone around the pipe. At the gravel section it is buried at the same depth as our control sectiorexcept at the area immediately under the pipe for a depth of three feet, the frost susceptible soil was removed an replaced with non-frost susceptible gravel. This is a traditional method and a remedial method for combating frost heaving.

Our final section is what we call the restrain section. It is buried at the same depth as the control section although we have

features incorporated into the restrain section so that we can apply various loads to the pipe and hence on to the freezing frost around itself in order for us to obtain information on how the additional load affects the rate of heave of the pipe.

The next slide, please. This shows the site just after it was leveled and before we started to put in the pipes. We leveled the site in order for the surface -- in order for the ground surface to be level with the water table that was down about 6 feet and we also dropped the ground surface from 2 to 4 feet in order for us to get closer to the water table in order to represent a worse case situation. This soil is a clay silt soil. We tested it by a standard trill test of frost susceptibility and the results showed us that this soil was rated as being highly frost susceptible. When I get later in the show and I show you some of the slides of our model box where we use the frost susceptible soil, you will actually see the ice lenses that developed in this soil clearly showing that the soil there was in deed very frost susceptible.

Next slide, please. This is simply a slide showing our ditcher diggin our trench and putting our back fill material up here, or the spoil material up there.

Next slide. This shows a trench that is 6 1/2 feet deep. The water table at this time, this was in November, was around 6 1/2 feet. You can see that water is starting to slick up on the bottom.

This shows you what a section of our buried pipeline looks like. It is four feet in diameter and 40 feet in length. The cold air from the refrigeration equipment came into this 28" inner duct, went along inside the pipeline, got deflected at the ends, came back along this anulus and then back to the refrigeration system.

This shows you -- just shows you the operation, just putting the pipe in the ditch and simply blading back some of the back fill material.

I put this slide in to show you just how the back fill material does slide around the pipe to get around below it.

I would now like to show you what each buried pipe section looked like in cross - section. This is a control section. This is a 4 foot diameter pipe buried in the ditch. The top of the pipe is 2 1/2 beneath the nominal ground surface. This is the spoil that we removed from the ditch and simply back filled and mounded over top.

This is a gravel section, again our 4 foot diameter pipe, the top of the pipe being 2 1/2 feet beneath the ground surface, the 3 foot section immediately beneath the pipe was replaced with the non-frost susceptible gravel soil.

This is our deep burial section, our four foot diameter pipe and in this case the top of the pipe was 5 1/2 feet beneath the nominal ground surface.

This is our restrain section. It was buried the same depth as our control section, but in order for us to have a mechanism by which we could apply a load onto the pipe and hence on to the freezing frost front as it developed, we had to place in piles as reaction members, put a collar onto the pipe and a restraining arm across-- a restraining frame across here such that if we put jacks in this position we could then put a load onto the pipe.

Next slide, please. This shows a slide of the restraining section as it was going in and these are the collars to which I refer. We then had a restraining frame put up and we had piles along the side to which we could hold it down. NOw, it is important to note that the jacks were such that we could put a specific load on that we desired and the pipe could heave or move as it wished at that over burden pressure. The jacks could travel and simply maintain their load. It is quite different from ordinary jacks where you just turn off the hydraulic system and the jacks do not move. --And the pressure just becomes greater and greater. In this case the jacks were such that you maintain the pressure that you wanted and the jacks would travel if the pipe wanted to move.

Next slide please. I would now like to describe some of the instrumentation that we had around the different test sections. We are looking in plan view, we are looking down on top of the pipe. This is the pipe in the ground, this

dash line. Across the centre line of the pipe we have a series of thermistor strings or inother words, methods by which we can determine the temperature of the ground at certain points and I will show you in cross-section what each of these instrumentations looked like around the pipe.

Q Could we have the spelling of that word, -- thermistors.

A Thermistor, right there, sir.

Q T.H.E.R.M.I.S.T.O.R.?

A Yes, sir.

Q Not like thermisses.

A No, sir,

Q No, right.

A At any rate, across the centre line of the pipe we measure the temperatures around the pipe in order to determine where the position of the freezing front is.

At these locations we have placed pull water pressure piezometers. These allow us to measure the pressure of the water around the soil, that is around the freezing frost bulb. If upon freezing the soil wants to heave, water must be drawn into the freezing frost front. For water to move it requires a pressure gradient and the reason that we put these piezometers in there was in order to measure the different pressures of the water at different positions around the frost bulb.

Q Now, Doctor, a

piezometer is -- I know it is shown on the bottom scale there, but is it P.I.E.Z. --

A -O.M.E.T.E.R., yes, sir.

Q Thank you.

A I did not really plan examining you on this later, sir.

Q We were also interested in the heave of the pipe itself of course, that being a central issue here and in order for us to measure the heave of the pipe we attached three 1-inch diameter steel rods at these locations. So that as the pipe heaved we could run elevations at different times to these rods and thereby determine how much the pipe has heaved over that period of time.

We also wanted to obtain the heave profile of the ground surface across the freezing pipeline. In order to do that, we put in heave gauges and perhaps I should explain just slightly what mean by a heave gauge. It is simply a round,thin disc that we place at a certain depth in the ground and we have a metal rod attached to it that rises up above the ground so that if the -- if there is any heave beneath that disc, it moves up the platen and the rod and we can determine how much the heave is by simply taking elevation at the surface.

In order to measure the heave profile across the pipeline, we put in heave gauges at these locations. Now, besides that we wanted to know what was happening within the frozen bulb of

soil itself from a heave point of view so we also dispersed our heave gauges at different depths around the pipe and at different distances away from the pipe and I will show you these in cross-section in a minute. We placed our heave gauges around, around the freezing zone or where we thought the soil was going to freeze, so that we could in fact get a heave profile of the ground itself at any depth.

Next slide. This shows you in cross-section where we located the different heave gauges. The heave gauges to give us the heave profile of the surface were located approximately a half a foot beneath the original ground surface and the other heave gauges were located at different places according to where we thought the frost bulb was going to progress and I would like to just draw your attention to the fact that each one of these heave gauges has in fact a steel rod rising to the surface to which we run an elevation in order to determine how much it has moved.

Next slide, please.

This shows you the location of our pore water pressure piezometers. The frost front starts to move around the pipe like that and we were interested in determining the pressure of the water at those locations.

This shows you our thermistor strings. This is what we call a a thermistor string and it consists of several thermistors and at each one of these points we are able to measure a temperature. WE have approximately 50 thermistors in each cross-

section and by means of those thermistors we are able to determine where the freezing front is.

WITNESS SLUSARCHUK: This shows us the ground that was frozen around the pipe on June 3, 1974, 75 days after we started the pipe. Along here we have the depth beneath the ground surface in feet, and across here we have the horizontal scale in feet going each way from the centre line of the pipe. All of this soil was frozen in here, at June 3rd. There was some naturally frozen soil in Calgary away from the influence of the pipe at that time, that is why the frozen zone tapers out in a fashion like that. If I had a slide of the position of the frost bulb in July or August, for example, it would look something like this. It would be down a little bit lower --

Q From the top?

A -- it would be down a little bit lower here because the warm summer temperatures had thawed it down a little bit farther. It would continue to freeze and therefore it would be down a little bit farther like that.

Q You're indicating that it would go lower, below the pipe?

A Lower below the pipe.

Q And lower above the pipe.

A And lower above the pipe, yes sir. Can I have this one, if you'll go back a bit. Along here, along this axis we plotted the depth of the frost below the top of the berm, this is the top of the ground above the centre of the pipe. You can see it is up here and it's about approximately a

foot and a half high. This is the original ground surface, the nominal ground surface that I'm talking about. Just to be clear, that is approximately the top of the berm, and that is the ground surface that I am referring to. The pipe is down 2 1/2 feet deeper, 4-foot diameter pipe, and this zone is the unfrozen zone directly under the pipe.

Now along here we have time and it's blocked out in months here. We atarted the test on March 20, 1974, and along here we have it in days. Now this dash line is the observed position of the frost front around the control section. This dotted line in the observed position around the restrain section. This solid line here is our predicted position of the frost front as assumed by geothermal analysis.

Q That's your computer program?

A That's our computer program where we account for the amount of water that has moved into the frozen ground zone by our predicted rate of heave. If we ignore the amout of water that was moving into the frost front due to ice lenses we would hope and predict on our production model with our computer program something like that. Above the surface, again the dash line is the position of the frost front. Over the string section the dash line is over the control section, and this is our predicted position. Our conclusions from this is that

we can reasonably predict the position of the frost bulb around the buried pipe.

This shows some of the heave data that we have obtained to the end of October. This is heave of the pipe in feet. This is one foot of heave so half a foot of heave would be somewhere about here. Along here again we have --

Q Dr. Slusarchuk, I can't read, maybe my eyes as well as my ears are bad what is the scale on the left-hand side?

A From here to here is one foot.

Q That's the whole line is one foot?

A The whole line is one foot. This is one foot up to here, so this is 4/10ths of a foot, 8/10ths of a foot, and one foot. Along here we have time blocked off in months, and also in days from March 20th. You can see that the control section started to heave along a line such as that, and you can see that it's tending to curve over somewhat as the frost bulb is increasing in depth, the load on the heaving lenses at the bottom of this frost bulb is becoming greater, and the heave rate is becoming smaller. This line here shows a deep burial, the heave of our deep burial section. This solid line is the heave of our gravel section, and this line here is the line of our restrain section. Now our restrain section started to heave along the rate such as that, and it is at this point that we added a load

to it. The load at this point was equivalent to adding three feet of additional overburden pressure. You can see that the general rate of heave decreased from there to approximately there. At this point in time we put on another load which increased the load by approximately another nine feet of soil or nine feet of overburden pressure, and it turned over to a rate of heave like that.

This shows that in fact as the load on the frost front is increasing the rate of heave of the pipe is decreasing. May I have the next slide, please?

This slide shows the predicted and observed pipe heave at the control section, and the control section is the section that heaved the greatest. Again this is heave in feet. This is the observed heave that is simply transposed from that block over there, and this is our predicted position. From an engineering point of view, we think that is quite in agreement and our conclusions from this is that we can reasonably predict the rate of heave of a pipeline in frost-susceptible ground. Next slide, please.

I would now like to shift to the second phase of our frost-heave study, and this is the laboratory phase on the 4-inch diameter sample that we obtained from the frost-heave test-site at Calgary, and also from sites along the pipeline route. We are running these tests in order for us to get

- to obtain the frost heave characteristics of soil samples at different overburden pressures. This is our test apparatus with a acrylic plastic tube encased in another acrylic plastic tube, and that is simply for us to minimize the radial heat loss when we freeze our sample. This is our soil sample in here. It is four inches in diameter and approximately four inches in length. We apply a pressure to the soil by means of this piston arrangement in here, so that we can put a desired load on the soil. If we start -- when we start to freeze the soil and it wants to heave at that overburden pressure, it simply pushes the piston up and we measure the amount of heave by having a diode gauge attached to the rod that is attached to the piston, and we therefore know how much heave is taking place within the sample.

In order for us to have unlimited access of water to the soil sample, and this of course is a very conservative feature of our test, we have(although you can't see it here) but we have a water supply right behind here in a burrette so that we can actually not only supply the water but measure the amount of water that is drawn into the soil upon freezing, when it grows ice lenses or in some cases water is expelled from it upon freezing when ice lenses are not formed. At any rate, the water table by means of these tubes is set in through, through the piston and made available to the sample here.

We freeze our sample by

having a sample on a freezing plate which we keep at approximately 30 degrees Fahrenheit in order for us to keep the thermal gradient into the sample, close to the thermal gradient we have around -- at the freezing front around our pipeline situation, we are trying to model as closely as possible all the aspects of the frost-heaving situation as it relates to our buried pipeline.

The freezing -- the freezing temperature is maintained by simply circulating cold fluid through these tubes. This shows the results of a sample after we ran our frost heave test, it is soil from the Calgary field test-site, it was tested at a pressure of approximately 500 pounds per square foot, and at the Calgary test-site this would be equivalent to the load at about five feet beneath the ground surface. As you can see, a lot of water must have been drawn into the frost front, and we measured what that was, and ice lenses were growing and in fact this is heaving at approximately at a rate of about two inches per month.

This is a sample from about two or three inches down below from the previous sample. We tested this at 2,000 pounds per square foot, in other words, about four times the pressure of the other one, and you can see that no ice lenses grew during this test, and our results from the water that we measured going in or being expelled from the sample actually indicated that as well.

Q That, Dr. Slusarchuk, was equivalent to how much burial or overburden?

A It depends on where the water table is, but somewhere in the order of 20 to 40 feet.

This is a sample of soil that we obtained -- I apologize for the picture being out of focus -- but it was a sample taken from along the pipeline route. It was a fairly fine-grained material,

as you can see, and it was tested at 2,000 pounds per square foot and again you can see that there were no ice lenses developing.

This is from another test-site along -- from along the field, from the field pipeline route, and again you can see that no ice lenses were developing, but in this case the pressure on the soil was only 500 pounds per square foot. The reason is that it is from a terrain type that is a delpaque type of deposit and it had more coarser grained material in it than the previous sample.

What does that visual picture tell us if we try to put it down into sort of a schematic engineering terms? Well, if we have the lensing heave rate increasing in this direction, and the load increasing in that direction, it shows us that at the low overburden pressures you get a higher heave rate, and as you increase the overburden pressure the heave rate comes lower and lower, until you come to a point which we call the shut-off pressure, the load at this point is called a shut-off pressure, where upon freezing, water is not drawn into the sample to grow ice lenses, and at the same instant it's not expelled either. It's right at that one point. Could you go back a slide, please?

Q Does that mean, Dr. Slusarchuk, that at a certain amount of pressure there is no more heave?

A No more heave, sir --

Q Water being sucked in?

A Due to water being sucked in.

Q Right.

A This is some of the data of our four-inch diameter frost heave test. This is from the Calgary test-site from all of the sections at a depth of six to ten feet. That is the area just beneath the frost front, just beneath the bottom of the pipe.

THE COMMISSIONER: Well, carry on, I think we can hear you.

A Now along this access we have what is called the effective stress or the load that is actually on the soil particles or the grain particles, or just in general terms the load on the frost front in pounds per square foot. Then you will recall that I talked about numbers such as 500 pounds per square foot and 2,000 pounds per square foot. Along here we have the net change in sample pour water volumes in cubic inches. That is not of much interest to you, of course, with regards to the numbers at this stage. In the next slide I'll show you something that will be of more interest to you, but what it does show you or what it does tell us is that at any point that is plotted above this zero axis means, above the zero point here, means that upon freezing water it was drawn into the frozen soil and discreet ice lenses were grown. These points plotted beneath the

zero point meant that water was not drawn to the frost front upon freezing. In fact it was expelled away from it. This would be the water that was naturally inside the soil pores themselves.

Now, what this shows then and is similar to that slide over there in the schematic presentation, is . as you increase the overburden pressure the amount of water that is drawn in or the tendency for the soil to draw water into the freezing front upon freezing is reduced. O.K., you can get a feel for that.

Now this is the same down here, effective stress or just simply the load on the frost front, in pounds per square foot as previously, and here we have the lensing heave rate in inches per month and again what this shows is that the rate of heave decreases as the load on the frost front increases. This is a take-off, this line here schematically is representing that.

I'd now like to talk about the final experimental phase of our study. This is the model box or the profile, what we call our model box, our buried pipeline model box test. This is the model box here, the soil about a ton and a half of soil that we obtained from the Calgary field test-site. This is our model pipeline in here. This is the end of it, it is three inches in diameter, and it's three feet long. It runs along the whole length there. In order for us to look into the pipeline and into the cross-section, as if we were just cutting

the ground in half, we put a one-inch acrylic plastic plate on the front so that we could look into see the position of our pipe and see the position of our frost front. Although it's not shown here because the picture doesn't include it, down at the bottom we have a two-inch layer of sand that is fully saturated and we have a channel all around this sand that is -- so that the sand is attached to water, and the water then is connected to a water table that is equal to the top of the soil, and that container is in the background here. You can barely see it back there.

You can see this is the first test that we ran, and that we didn't keep it flooded at the surface. Can I have the next slide, please?

All subsequent tests, we did keep the surface flooded so that even though there was unlimited water supply available to the freezing frost front from below, as in the first one there also was an unlimited supply of water for heaving from the surface. This certainly is a worse case sort of a situation.

We are now looking perpendicular to our acrylic plastic plate looking right into the pipeline which is here, the soil which is across here, and the water which is flooded across here. This is the second cycle or the start of the second test. The first test we started, the pipeline was initially in this position here.

Q Shown by the black circle there?

A Yes sir, shown by the solid black circle. Now the point that I would like to make here is that when we tried to put in the soil, this ton and a half of soil, we couldn't compact it to the same density and the structure that was equivalent to the field test-site, although this is what we were attempting to do, and what happened, as it started to freeze in the first instance and the frost bulb grew around it, ice lenses grew but the pipe was not really moving, and we were a little bit perplexed about this, we were wondering just why that was happening, and the reason was that it was consolidating the soil directly underneath it, and what this indicates then is that if you have a loosely consolidated or a poorly consolidated soil, such a soil for example, if you're going under a river crossing or shallow bay or something like that, you start to operate your pipe and you may grow ice lenses but the pipe itself will not move that much, the reason being that it is consolidating the soil itself, it is drawing water out from the soil immediately in front of it, consolidating the soil, and that consolidation is compensating for a lot of the heave, and the result is, and it's clearly shown here, when we thawed the whole thing out, the pipe in fact did settle down and the ground surface settled down too, because this area of the soil was more consolidated. So we feel that this is a very beneficial effect.

I'd now like to show how the frost bulb grew at different times in this second cycle. Could I have the next slide, please?

In this -- at the start of the test the pipe was initially at this dashed line, 40 hours later the pipe has moved up to about here, and you can see that the frost front is around here. If you were as close as I am, you could see that there are all kinds of ice lenses growing all around the pipe in the frozen zone. I'd like to draw your attention to the fact that the load on the frost front is extremely small, only equivalent to maybe less than 100 pounds per square foot, so that if you recall the rate of heat curve versus overburden pressure you're on the very highest point of that curve.

This shows the position of the frost front, the amount of heave and so on, after the test was running for about 30 days. You can recall that the pipe was initially in this position. It's moved up approximately three inches. This is the position of the 32-degree isotherm or the freezing front, and you can see all the ice lenses that have been developing in that -- during that test.

I would just like to draw your attention to the fact that there is very small over burden pressure on here. The next slide shows you the same test but with an overburden pressure applied to the pipe. We had a piston arrangment, two pistons at the surface, by which we could apply a load to the pipe and in fact put a surcharge on the pipe so that the load came down on the pipe and was distributed in an area more or less like this, there was no load placed on that soil up in there and you can see the significant difference in the ice lensing characteristics in the soil in this particular area compared to what is in this area or compared to the previous slide.

I should like to summarize the information that I have presented to this point by saying that the results from the field test site, the model box and the laboratory field heave tests clearly show that the rate of heave is significantly reduced as the load on the frost front increases. It was shown that at loads greater than the shut off pressure, soil does not draw water into the freezing zone, but in fact some of the local water is expelled away from the freezing front.

The consequence of this is that no lensing frost heave will occur at over burden pressures greater than the shut off pressure due to water being drawn into the freezing zone.

I should now like to illustrate by means of an example how we use this information

in determining the amount of frost heave of a pipe and how we can reduce the amount of -- how we can reduce this amount of heave if it is considered to be excessive.

Let us take, for our example, or I am taking for my example, a four-foot diameter pipe buried in unfrozen soil that is highly frost susceptible at the field test facility in Calgary. The pipe is operated at a temperature of about 10°F with the bottom of the pipe being located at a depth of about 8 to 10 feet beneath the ground surface.

In order to consider a worse case situation it is assumed that the water table is at the ground surface so that the supply of water to the freezing zone is unlimited and that the bouyant effect of the water minimizes the load exerted on the frost front.

We make use of our geothermal analysis in order to predict the depth of the frost front beneath the bottom of the pipe as a function of time in years after the pipe , after start up. For example, this is after about ten years, the depth of the frost front beneath the pipe would be about 25 feet beneath the bottom of the pipe and if the pipe was 8 to 10 feet beneath the ground surface, this means that the frost front is now around 35 feet beneath the ground surface and indeed a significant load against which the ice lenses must act against.

ONce we know the position of the

frost front, we can calculate the load that is in the frost bulb, because the ice lenses have to lift up the whole frost bulb and we therefore then have a load as a function of time on the frost front. We know the heaving characteristics of the soil and as I mentioned, for this example, it is a highly frost susceptible soil that I am taking for my example, similar to that at the Calgary test site. We know the load, the time relationship, we know the heave pressure calculated on the -- the heave load characteristics and you can therefore predict a heave.

May I have the next slide, please. You can see here of course that the curve -- the frost front does penetrate a lot faster in the earlier years than it does in the later years.

This is a heave curve then and this is the heave of the pipe in the ground surface in feet. Okay, this is one foot, two foot, two feet and six feet. Along here we have time in years. In this case we would predict that the total heave would be somewheres around six feet. Of that six feet this portion of the heave would be due to the water that was sucked or drawn or migrated into the frozen zone from the adjacent unfrozen soil. This portion of the heave --

Q The first portion, Dr. Slusarchuk, was about -- accounted for how many, four and a half feet?

A Yes, sir, closer to five feet, I would guess, a little over five feet.

Q And that is due to water migration?

A Yes, sir.

Q Right.

A Now, this portion of the heave is due to the natural expansion of water upon freezing.

Could I have the next slide, please. Now this is a same sort of a slide with the heave of the pipe and the ground surface in shape exactly the same scale and time I believe is exactly the same time scale. This is the same curve that I showed you before, the top curve, the total heave curve. At that time as I was saying we were assuming worst conditions and that the water table was at the ground surface.

If for example, we had buried the pipe an extra five feet deeper, put it down to 13 to 15 feet, for example, although it is not shown on here and labeled as such, the heave would have been reduced to a line such like that. That is still considering the water table at the ground surface.

Q With some pressure on it.

A No, sir, at this time I have not got to that stage. Just deeper burial. We just buried the pipe deeper and we reduced the heave from say about six feet to four feet by burying the pipe deeper.

Q How many feet deeper?

A About five feet, sir.

About five feet deeper. Now, if we considered this -- this heave excessive for example and we did not want to bury it deeper -- we could put two and a half feet of surcharge at the ground surface, still assuming that the water table is at the ground surface and again we would follow a heave curve something like that. In other words our two feet of surcharge would have effectively reduced our rate of heave from about six feet to a little bit under four feet. If we would have added five feet of surcharge under the same condition we would have reduced our heave to approximately two feet.

Now, in all of these cases, it has been assumed that the water table has been at the ground surface or in fact above the ground surface if you had a ponded area and remained there for the whole year, for the whole year through. Now --

Q Would that be a worst case, Dr. Slusarchuk?

A Yes, this is a worse case situation. Now, we know that though in a lot of cases the water table does not stay at the ground surface all year round. It drops down, say in the winter, for example, and in other areas such as on slopes, for example, the water table will not be at the ground surface. If for example, the water table was at about five feet below the ground surface, without any surcharge or without any deeper burial, just by having the water table removed from the ground surface to five feet below the ground surface, we would have been on

a curved line such as that.

Now, these graphs show us that most of the heave occurs within the first few years of operation. It is also clear that heave in the order of a foot or two requires a year or two to develop, even under worse conditions. Consequently if by monitoring areas are identified as heaving at an excessive rate, there is ample time to implement remedial measures so that these measures can be carried out at the most suitable times.

In summary I should like to state that the results of these studies have led us to the conclusion that we have a rational method for assessing the potential for frost heaving along the route and for predicting the heave of the pipe and ground surface. If our predictions indicate that excessive heave may take place, then preventative measures such as deeper burial or a surcharging the ground above the frozen zone of soil will be an economical and effective means of keeping the amount of heave within acceptable limits. The key reports upon which we rely are the two reports published by Northern Engineering entitled "Frost Effect Study" dated May 1974 and "the results from frost effect study" dated March 1975. Thank you , sir.

THE COMMISSIONER: Thank you very much, Dr. Slusarchuk.

MR. GENEST: Would this be a convenient time for the break.

THE COMMISSIONER: WE will take a break for coffee.

(PROCEEDINGS ADJOURNED)

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

MR. GENEST: Q Sir, if I could address a question to this presention by Dr. Slusarchuk to Dr. Morgenstern, who has experience in this particular field of endeavor at large, do you have any comments to make, Dr. Morgenstern, in connection with the tests and the results that were obtained by the tests as described by Dr. Slusarchuk?

WITNESS MORGENSTERN: Yes, I'd first like to comment that the pipeline application Assessment Group were entirely correct with the information that I think they had available to them to draw attention to this problem, and that the ability to predict magnitude and rates of frost heave, certainly at the time that they were working, was relatively poorly understood. Indeed, I drew attention to this in a State of the Art paper myself at the last International Permafrost Conference a few years ago.

However, the central physical idea that the method just described relies on is that the increase of overburden pressure can be utilized to control the magnitude and the rate of frost heave. This particular feature has been known for some time. The early researchers in the area of frost heave mechanics were aware of the phenomenon. However, it lay rather neglected in the literature because most of the concern in practice regarding frost heave has to do with roads where they're subjected to clyclic freezing and thawing, and the overburden pressures are rather low, the order of a few feet.

So that a systematic investigation of the role of overburden pressure had not been undertaken. I think it's fair to say that we began,initiated the first -- if perhaps not the first, one of the early systematic explorations of this effect at the University of Alberta a few years ago. There are also field studies that have been undertaken by the U.S. Corps of Engineers, in their Cold Regions Research Group that support the idea and could also -- we could also cite, and I suspect some of our literature does cite their data as supporting the principles here.

Subsequently, Northern Engineering and Canadian Arctic Gas took up the idea in the systematic development that we've just seen that embraces laboratory studies, embraces field studies, embraces model studies and there are also some theoretical considerations that underly it, and this has led us to rational design procedures that in my view represent a major technical achievement.

Q Thank you. Dr. Clark, does that end our discussion, at least at this stage on the problem of frost heave?

WITNESS CLARK:

A Yes sir. I'd like to turn to the concerns expressed in Section 8.2, the buried pipeline rationale, pages 179 to 181 of the PAG Report. Now the concerns expressed in this chapter,which are not discussed elsewhere, which is to say frost heave, drainage and erosion control, they are primarily related to whether or not the pipeline should be

buried for the full length of the route throughout permafrost areas. A discussion of this concern was presented in response to Question 24 of the PAG request for supplementary information. At this time no areas have been identified where it would be of overall benefit to construct the line above ground.

Q Question 24 specifically referred to a proposed burial mode of construction, does it, Dr. Clark?

A Yes sir, and provides some comparison of burial mode versus pile support, versus what is called berm construction.

Q Did you participate in the preparation of the answer to that concern.

A Yes sir.

Q And as I read it, without reading the whole thing into the record, it has tables and it lists the advantages of raised or above-ground construction and the disadvantages and concludes that the disadvantages far outweigh the advantages.

A Yes sir, we tried to look at it from an overall benefit point of view. In our view we have not identified any area where there would be an overall benefit to constructing above ground.

Q Next, sir, I believe you're going to deal with the concerns expressed in Section 8.5 of the Pipeline Assessment Group report, which deals with slope stability and erosion susceptibility. These, I understand, are at pages 191 to 200.

A Yes sir.

Q Of the report.

A Yes sir, and this is one of the major areas which we find is expressed throughout the concerns in the Assessment Group, and rightly so. We have submitted responses to which I will refer later, but before getting into the detail that I have here, I think it would be of benefit to everyone here to have an overview of slope stability and I would like to turn to Dr.Morgenstern and ask that he provide this for us.

Q Would you proceed, Dr. Morgenstern?

WITNESS MORGENSTERN: The concern for slope stability is essential in the design of any transportation pipeline, highways, railways, any of the facilities that go across permafrost terrain the safety of the system and the physical environment could both be threatened if the slope problem is not handled correctly.

For example, the slope instability could arise at river crossings along right-of-ways associated with cuts and even off the right-of-way and threaten the facility. It enters into many phases of design. Now until about 45 years ago our understanding of the problems associated with landslides and permafrost terrain was rather limited. There had been numerous descriptions of mass movements of various kinds but the mechanics of these processes were not well understood. The understanding of the mechanics of the processes and their inter-action with

the geothermal effects, the influence of terrain disturbance and changing ground temperature, the effects of induced thaw, this inter-action is necessary in order to establish positive engineering design procedures that are to go beyond the rather qualitative description of the geomorphologist, perhaps the geologist, we have to get a quantitative understanding of processes.

Now as the pace of northern development quickened, it became apparent that more studies were needed and research programs were launched by government, universities and industry, including studies supported by Canadian Arctic Gas. In retrospect, these studies were not planned as co-ordinated units, but it appears now that they have to a large degree been complementary to each other.

They have led to a clear understanding of where landslides occur in permafrost terrain, how to calculate the likelihood of their occurrence, and how to design stabilization measures to prevent or inhibit them; and it's the purpose of my presentation now to illustrate some of the findings that have brought us to this position.

One of the first things that we do when we try to make sense out of a complex subject at an early stage in its development is to attempt to establish a classification. The classification that we have developed was based upon the morphology of movement, the shape of the material that is moving. There is some conflict among some of us regarding

terms, but by and large the descriptions that I'll be citing are, I think, accepted by other workers in this area. The basic structure of the classification is to separate the shape of the material moving in permafrost terrain, whether it is a flow, a slide or a fall. In the case of a flow, it gives the appearance of being rather viscous, it has a high degree of mobility. In the case of a slide, the material that's moving is more intact, it stays much more coherent as it moves; and in the case of a fall the nature of the movement is a rotation forward, and that is simply illustrated by the word "fall".

Solifluction is a rather shallow type of flow that we don't encounter -- that we perhaps encounter very rarely on pipeline routing, in any case it is very shallow and I won't address it further here. It is an interesting phenomenon in the Arctic that doesn't bear on our pipeline because it is buried too deep for it to be of concern. It also falls on rather minor movements, they contribute to lateral channel migration. Some of our river people will be talking about it, but they are also not a major concern along the pipeline. We will deal mainly with the skin and bi-modal and multiple retrogressive flow and that type of slides.

I would like to illustrate, to give you a visual picture of what these different components of classification look like. The first slide is a picture of a skin flow. Skin flows are rather plainer features following by and large the

level of the ground or the taking part mainly in the active layer, or perhaps a thickened active layer as we see here might have been thickened in response to a forest fire. This particular flow is on the Hume River. In this area where we undertook extensive observational work, flows are very abundant. We find that we can identify the likelihood of flows with different terrain units, in particular here, we have glacial lake basin sediments which are very disposed to this type of mass movement.

Perhaps useful to note that in some particular areas land slides are very abundant as a naturally occurring process and perhaps the evaluation of the physical impact of any transportation facility should be looked at on an incremental basis.

The new landslides might facility generate in a specific terrian type. The second type of flow is bi-modal flow. This is a bi-modal flow along the Mackenzie River near Fort NOrman. The bi-modal flow is characterized by a rather plainer lobate feature that you see coming out into the river and a steeper head scarf that we see back in the tree lines. We have adopted the term bi-modal becaause the shape of the slide has a bi-angulàr shape and thereare two processes participating in the mass movement. ONe, the outward flow of material towards us and the other the ablation or the melting out and regression in the head scarp back into the upland.

These are very interesting flows. They in some locations demonstrate an extremely rapid rate of degradation of the head scarp, measured in the order of tens of feet in a thaw season. The energy balance at the interface in the headscarp is somewhat complex. It contributes to this very rapid rate of regression. We feel we now have a much more quantitative understanding of what is going on there.

Here is another bi-modal flow that occurs naturally in the Richardson Mountains. You see the material flowing out toward the right and we will see in the next slide in the head scarp shown dark toward the left centre portion of the slide, a very ice rich matieral that is the source of this ablation.

This is the ablating head scarp in the last picture. Now, when a flow, be it skin or be it bi-modal, takes place, they need not go on forever. There are examples in nature of bi-modal flows, for example, that have self-stabilized. Here is one also on the Mackenzie near Fort Norman that has stopped moving. Vegetation is becoming restored and the mass is becoming quiescent.

Our researches and understanding of the mechanics involved in bi-modal flows lead us to the view that the key to stopping this rather rapid upland degradation is to stop them early on. Do not let the process of ablation get started. So that we will see later on where we think that such a process might get started, we would recommend certain stabilization measures in the event of a risk of such a thing.

THE COMMISSIONER: Excuse me, Dr. Morgenstern, that word, "ablation" --

A Melting out.

Q Could I ask a question. Skin flow, is it putting it too simply to suggest that that is simply a flow of the active layer?

A Or a thickened active layer that has been thickened in response to vegetation disturbance and forest fires, yes. This is certainly an excellent picture that would parallel a part of or all of the active layer, yes.

Now, the multiple retrogressive flow is a composite that works back into the

upland. It has a somewhat more complex shape and I have not included a slide here, but it also is rather low banked, rather viscous in its morphology.

Let us turn now to slides. You remember that the characteristic if we call something a slide as opposed to a flow, it is more blocky, it is kinemetic, the nature of its motion has kept the mass movement more in tact.

These are multiple retrogressive slides along the Mountain River. In fact just around the corner from the Sans Sault Test Site that Mr. Williams described to us yesterday. These are large slides. If a pipeline were to traverse an area and a slide of this kind occurred, there is no doubt that it would be troublesome. This type of slide is relatively rare. It occurs when the slopes are steep, high, by and large involving fine grain sediments. The location of slides of this kind are readily identified on airphotos and clearly route location has avoided areas where this type of slide does occur.

Nevertheless, we have a few locations where there are relatively steep, high slopes in relatively fine grained terrain where we propose to evaluate whether such a mechanism might take place.

The block slides instead of having the retrogressive behaviour are simply slides that appear to have slid down and out and I will not go on with further description of the

characteristics within the classification. Now, our procedure has been with this terminology, this frame work in our mind with an idea of the terrain units in which these kinds of slides, mass movements occur has been to inspect the route and identify all slopes that we think have a potential for instability.

This illustrates the results of the analysis along the route, giving a matrix of slopes, slope height against / slope angle. The details of the specific slopes are given in one of the supporting documents that I will cite towards the end of the presentation.

We have assessed that slope angles steeper than 3° in terrain unit in which fom our studies know can generate mass movements are slopes worthy of further consideration, that is to say, inspected in detail design. Notice that of the 686 of the 700 slopes that we are discussing, perhaps half of them lie in very gentle inclinations and are rather low. The height is not effected.

The criteria with /which we have selected these slopes are conservative and further analysis underway leads us to believe that a very large percentage will be shown to be of no special concern not needing detailed analysis.

Now, when we undertake detailed analysis we have to do certain calculations. Slope stability can be aggravated by thawing. If, for example, we come along and clear the right-of-way as we will, the energy balance at the surface of the

ground will be changed, permafrost will digress some degree and water will be released in the soil and this will aggravate stability.

In order to analyse these things quantitatively, using procedures outlined in detail in supporting documents, we need to know -- we need to be able to predict the ground temperature regime as a function of the changes that we are going to induce. We need to know something about the strength of the soil. We need to know something about the drainage charactistics of the soil, the hydraulic conductivity if it has been a parameter cited recurrently here. We need to know something about stratigraphy, the variation of the ground properties through the section.

In some locations we feel that we can estimate the relevant parameters that I have just listed to an adequate degree of certainty, to undertake the analyses that we will do and in other locations detailed field studies will be undertaken to get the ground truth or site specific data that will be part of the final design.

This process then will determine whether a slope is stable or not. In the event that stability is a problem, stabilization schemes, that I will describe presently will be implemented. The criteria that we will invoke clearly to insure that the integrity of the pipe is not endangered and to insure that any intrusion into the physical environment is acceptable or that is, we will not

create an unacceptable location or number of slides and this will be done at the outset.

Part of the things that we would think about, whether for example, if there is some threat of instability occurring and if for example it is a location that would be difficult to get to after construction, it would be more prudent to stabilize at the outset rather than to run the risk of having difficulty getting in subsequently in a maintenance program.

On the other hand, I think I should point out that it is not our intention to avoid all landslides at the outset. It is a better solution, in my view, to treat some as a maintenance problem provided they are the kind that can be controlled by the maintenance program. Not for example bi-modal flow that might degrade very rapidly in the fall season -- that is best handled at the outset.

As we pointed out in the slide before, some slopes when mass movements occur reach natural equilibrium, on the other hand, others have to be treated artificially. It is instructive to look at the experience, some of the experience that has been gained and is still being gained in Alaska where they are now cutting and treating slopes.

This is the cut along the Trans-Alaskan Pipeline haul road that was constructed some years ago and it has been dubbed, the "tunnel of ice". During this cut, they exposed a terrific

amount of ice in the wall of the cut and we are looking, and it is unfortunate that I do not have this in colour, but essentially that is pure ice, clearly a situation that is going to degrade and at the outset it was thought that the degradation would be a very -- it would inhibit the use of the road and the material would create a lot of construction problems.

Subsequently, the self-stabilization has taken place, the material did degrade, organic material fell over and has healed the slope to a large degree. During my visit to this cut last fall, this in fact is what it looked like. The healing could have been even a little better if vegetation had not been stripped off the top of the upland. There is a small reventment, you see a little rock channel down there which has helped collect the debris during the ablation or melting out of the material and it subsequently insulated the face and that is now a stable situation with revegetation -- with vegetation becoming restored.

Some people have drawn the conclusion that it is appropriate to make cuts vertically in permafrost as they will ultimately stabilize themselves. We recognized, however, that this was not necessarily true. In fact the good behaviour in this location is due to the peculiar type of ice form, it's wedge ice ice wedges which I'm sure Dr. McKay must have discussed with you two weeks ago. In this case, the ablation proceeds until the system runs out of ice, and then you have enough unfrozen soilas a seal, which then drains and becomes stable. On the other hand, if ice is present in extensive tabular form, horizontal layers extending for large distances back, it is unlikely, in our view, one could not rely on self-stabilization of this kind occurring. More positive stabilization steps would have to be undertaken. If you didn't do that, you'd run the risk of one of these extensive bi-modal flows developing.

Here is a cut in the Dempster Highway near Ogilvy River, it's degrading very substantially, the result of the construction practice employed there. The degradation has subsequently been stabilized by dressing with a gravel layer, provides support, provides drainage, provides some insulation value, and during reconnaissance this appeared to be behaving well, and I draw to your attention that here is an example of stabilization measures that have been shown to work in the field in our construction practice.

Well, let me now go through some of the stabilization measures that we would employ

as part of the final design, as one going through a slope by slope analysis.

One configuration, let us develop the following scenario . Our analysis of thermal effects indicate that permafrost is going to degrade and essentially there is a danger of a skin flow developing along this slope. We have developed methods of analysis that tell us that we can stabilize that situation by putting on a sandwich that is composed of insulation, drainage pad underneath, and gravelly sand underneath, an insulating layer, and then perhaps further surcharge that can be designed to accept revegetation. This blanket would be in the order of several feet thick and would combine insulation and combine drainage and the mechanical analysis and quantitative analysis that we use to evaluate the stability of skin flows tells us how to design these sandwiches in a rational manner.

We can also introduce internal drainage, which of a certain type draw water, draws the water in a a very influential way, a proven way of augmenting stability where that would be needed. This is one configuration for one type of potential mass movement.

If a crack were to be made in thaw stable permafrost material, then our evaluation of the terrain leads us to believe that water, as it is generated by melting, will freely drain-out leaving the ground in a coherent state that one can simply cut the material, try to disturb the uplands

as little as possible and put back, install here erosion protection revegetation programs, so that it can thaw without any untoward effects. Thermal degradation of permafrost is not necessarily a bad thing. It only creates construction problems by and large when there is a lot of ice around and the water can't get out.

Some cuts we will choose to make in a vertical way and we recognize that the organic overhang itself contributes greatly to self-stabilization processes, so we would try as this degrades, to design and augment the resistance of this overhang so that it would break over the degrading slope and then provide insulation to inhibit further ablation, thermal degradation of the material behind the cut. Some channelling abutments would be placed here in case material flowed out. This, we think, would be quite effective particularly for the smaller cuts.

In other cuts, another procedure would have to be adopted, if the cut is somewhat higher than the previous one, we identify the possibility of a bi-modal activity developing. This is ice-rich permafrost, then a positive cover involving a draining capability involving insulation and providing revegetation on the surface would be designed at the outset, or brought in later if this were a slope treated as a maintenance project.

The general point that I would draw your attention to is that there is this array of different solutions available to us, depending on the range of configurations,

soil type, ground ice type, height of slope, location, and so on. There isn't one single solution. That will be brought to bear on this kind of a slope, but many solutions will be utilized for site specific design. Now, let us look at one of the large high steep slopes that is of concern to us. This in the rather cleared area, moving down the river, is the location of the major crossing of the Great Bear. This particular location is a relatively high slope, quite steep, it contains fine-grained soil, and we recognize here the possibility -- I suggest just a possibility -- of deep-seated failure, there isn't a deep-seated failure there, but our experience tells us that we should expect the possibility of failure at this location. We also recognize the need to inhibit any toe erosion to stop the more shallow types of degradation which might occur. I note that the pipeline application Assessment Group also has drawn attention to this crossing and queried it.

The viscidity at the crossing here, based on information gathered from field studies and displayed here in simplied form, is frozen sand overlying frozen clay, underlain by some unfrozen material and the river sitting on bedrock in that sequence, sitting on bedrock. This is a configuration not unlike that that we encountered at Mountain River where we found large slides and therefore we investigated and have investigated the potential for deep-seated failure in this location. If we assume that

that slope is at the point of failure, and I add that it doesn't exhibit any characteristics of that, therefore this is a conservative slide and if we put the berm in the river along the toe of that slide to add a counter-weight, so to speak, at the base of the toe, we can increase the stability of that slope by about 40% which in my practice and in most of our practices will be regarded as an acceptable degree. We also recognize that this configuration might have some possibility for creep in frozen material, and in fact people in the field at this very time are evaluating some aspects of that, this type of solution because it decreases the stress level in this material will also decrease the possibility of a creep.

THE COMMISSIONER: The crossing of the Great Bear River that we're looking at in the slide, I take it that's the north slope?

A Yes.

Q And how far are --

A South slope. North face on the south slope.

Q Let's just think about
WITNESS McROBERTS:
that for a moment. You can see the Great Bear River coming around here. This is the Great Bear coming around, the Great Bear is still here and this is --

This is the south side of the Great Bear.

Q All right then, we're on the Fort Norman side of Great Bear River.

A Yes.

Q How far are we from Fort Norman?

A Four miles.

Q Oh, I see. You confused me. I thought that might be the Mackenzie we are looking at in the distance. I am oriented, thank you.

WITNESS MORGENSTERN: So we see then that this provides in the event of a potential deep-seated failure and also contributes to ameliating creep, if creep is identified as a problem.

Q Excuse me, Dr. Morgenstern, you plan to establish a berm at the toe of the slope, if I'm using the terminology rightly. Now, does the word "berm" connote anything more? If it does, tell me, than simply filling in the toe so as to reduce the angle of the slope?

A It provides weight on the toe and reduces the overall length by loading the toe, surcharging it makes the material stronger. The organ of strength lies in friction and this increases the load to immobilize the friction.

Q Could you go back to the last slide so I can compare that with this one? We had the slope without the berm, I think, didn't we?

A Yes, we did. Does that help?

Q Yes, I see, yes.

A The details of --

Q Excuse me, so that berm would extend out in the river would it?

A That would be designed to meet hydraulic criteria as well. The influence of the berm would have to be assessed hydraulically.

Q The berm itself would be restrained by piles and so forth, or would it consist of gravel?

A Consist of gravel and would have erosion protection on the surface.

The details of the methods of analysis, the distribution of potential unstable slopes, or at least slopes requiring detailed investigation, the classification and the terminology that I have utilized here are given in the responses to requests for supplementary information, and also in the report on slope stability and permafrost terrain that has been listed, on which we rely, and that report also includes worked examples. In summary, then, we see that the concern for slope stability which arises in cuts, it arises, as is stated, with thawing along the right-of-way, it arises in river crossings, it even arises in naturally occurring things which might potentially attack the integrity of the system.

This concern has been addressed in systematic manner. Key problems peculiar to permafrost terrain have been resolved. The results of these studies have been applied in the design of this pipeline, so that with regard to considerations of slope stability, in my view this pipeline can be constructed in a safe and environmentally acceptable manner. Thank you.

THE COMMISSIONER: Thank you Dr. Morgenstern.

MR. GENEST:

Mr. Goudge reminds me, and perhaps I should, in case I forget, I should remind the panel that the slides will remain here for the purpose of cross examination, and as usual they will be compiled by the witnesses and filed permanently with the Inquiry.

THE COMMISSIONER: Yes, thank you Mr. Genest. Could I ask a question, before it slips my mind? You have proceeded on the assumption Dr. Clark, you and your colleagues, as I understand it, that you do not have permafrost beneath the river crossings. That is, in the beds of the rivers. Correct me, if I am wrong, in putting it in that way?

WITNESS CLARK:

A Under the wider rivers sir, we have assumed that there is not permafrost. We have done some drilling under the major rivers, but along the Arctic Coast for instance, under a river approximately 200 feet wide, there would be permafrost found at a depth of the order of 40 to 60 feet below the river bed. By and large, the portions under the

rivers and under the lakes, are unfrozen.

THE COMMISSIONER:

Q Well, the major river crossings within the Yukon and the Northwest Territories, the crossing of the various channels of the Delta, and the crosssing of the Bear River and the crossing of the Mackenzie, those are the major river crossings now?

A Yes, sir.

Q Now, has Arctic Gas carried out tests to determine whether those river beds are free of permafrost so far as the levels of the river beds that we are concerned with go?

A Yes, sir, we have conducted drilling in the beds at the Peel River, the Swimming Point Crossing, the Point Separation Crossing, and the Great Bear Crossing.

Q And those are free of permafrost?

A Yes, within the depths that we explored, which is below the depth to which the pipeline would be buried.

Q Was the Mackenzie free of permafrost at Burnt Island before you --

A Yes, sir, below the river.

Q -- and the Liard was free of permafrost?

A Yes, sir.

THE COMMISSIONER:

Yes, thank you, carry on.

MR. GENEST:

Q Well, then, Dr. Clark, may I take you back them to your testimony with reference to the Pipeline Assessment Group concerns relating to slope stability and erosion. We've had Dr. Morgenstern's presentation and we have a concern expressed by the Assessment Group at page 193, that the proposed route has considerable potential for slope failure. What is your response to that sir?

WITNESS CLARK:

A Yes sir. Well, with Dr. Morgenstern's overview as a background, I would like to respond now to these concerns.

With respect to the proposed route having considerable potential for slope failure. Our response, from the studies we have conducted on behalf of the applicant, we do not agree that the proposed route has a "considerable potential for slope failure". A summary of the number of potentially marginally unstable slopes found along the right-of-way is contained in the Response to the PAAG Request for Supplementary Information, in Appendix B., and was illustrated by Dr. Morgenstern. While only a small percentage, in the order of 2-3%, of the route, exhibits potential instability on the basis of conservative criteria, we expect that further study will substantially reduce this amount. And as Dr. Morgenstern pointed out, approximately half the slopes are in the range of three to six degrees and less than 40 feet in height.

As to the remainder, it is

intended to apply preventive stabilization techniques to ensure a geotechnically sound and environmentally acceptable design. These techniques are discussed in the Responseto the PAAG Requests for Supplementary Information, in Appendix B.

The next concern relates to Slope Stabilization. PAAG states on page 193 that "Slope stabilization measures proposed for permafrost areas, however, are described in such general terms that the Assessment Group is unable to judge their probable effectiveness".

Our response: the stabilization methods that could be applied, where necessary, to ensure the stability of all slopes along the proposed right-of-way are discussed in Appendix B of the Response to the PAAG Request for Supplementary Information and in greater detail in the NES report "Slope Stability in Permafrost Terrain" dated December 1974, and I'm referring to this report which I hold here, and to which Dr. Morgenstern referred.

Q Appendix B is a paper entitled "Some Aspects of Natural Slope Stability in Permafrost in Relation to the Applicant's Proposed Pipeline" And it contains some fifty pages of technical data and information, and unless Mr. Scott would like me to deal with it at length, I would not propose sir to read it all into the record. But I'm in the Commission's hands in that regard.

THE COMMISSIONER: It appears it isn't necessary.

MR. GENEST:

Thank you sir.

WITNESS CLARK:

A Turning now to the several concerns relating to the method of analysis that the Applicant considers applicable to shallow slope failures. These concerns are listed by PAAG in Section 2, Part (ii) page 193.

Firstly, it's suggested by PAAG that the analysis involves costly field sampling and laboratory testing in order to undertake a design. The testing required is similar to that undertaken as a matter of course in most geotechnical testing laboratories and is not so unduly expensive as to restrict the amount of testing that would be required. However, it is not intended to acquire site specific information for every slope that might fail in this mode. Rather, where appropriate, typical slopes will be investigated within each terrain unit and designs evolved on a mile by mile basis.

Secondly, a concern has been registered in Appendix I to Section 8.5 concerning the magnitude and range of the coefficient of consolidation parameter. In Appendix I a value of $c_v = 5 \times 10^{-4}$ cm^2/sec was quoted and then it was varied by one order of magnitude lower to a value of 5×10^{-5} cm^2/sec in order to show that the Factor of Safety was significantly reduced depending upon c_v. While the parametric study conducted is quite correct the approach is not completely appropriate. The value of c_v quoted in Appendix I is

is based on testing of remoulded soil samples which were never frozen during the testing procedure. On the other hand, testing of undisturbed, initially frozen soil samples of natural permafrost indicates that the presence of cracks and fissures inherited from the ice vein structure significantly increases the magnitude of c_v. I would draw your attention back to the slide that Dr. Slusarchuk showed of a sample, where ice lensing had developed in the cracks and fissures which were clearly apparent in that slide.

Now, this phenomenon is considered in detail in the Respons to the PAAG Requests for Supplementary Information, Appendix B. That is, that if the effect of structure inherited from thawed ice is to be considered, it is more appropriate to conduct the parametric analysis of Appendix I, Section 8.5, in the opposite direction and to show that the ratio of the Factor of Safety increase rather than decreases. Finally it is also of interest to note that the value of $c_v = 5 \times 10^{-5}$ cm^2/sec is rarely, if ever, encountered in geotechnical practice. More commonly, values of c_v of from 10^{-2} to 10^{-3} cm^2/sec are to be expected in thawed permafrost soils.

The third item introduced is that the Applicant has not identified the criteria that would be required in identifying slopes requiring analysis for potential shallow slope failures. Information in this regard is contained in the Response to the PAAG Request for Supplementary Information, Appendix B and in the NES report entitled "Slope

Stability in Permafrost Terrain", dated December 1974.

Finally, a concern is also registered in a discussion of the statistical significance of the Applicant's position in regard to shallow slope failures. We take the view that there is little practical value in undertaking an analysis as suggested in Appendix II, Section 8.5. While such an approach can be formulated, such techniques are rarely used in geotechnical practice.

Q Sir, I think I'll tell my grandmother to skip all this, and leave that to Mr. Scott and his technical advisors. I find it very difficult to attempt a layman's explanation of that response, and it should be, at least in my view, left to the scientists to contend with.

THE COMMISSIONER: Yes, I think we'll leave it to Mr. Scott to go into that.

MR. SCOTT: I'm going to need a little time.

(LAUGHTER)

THE COMMISSIONER: We'll get you a blackboard.

WITNESS CLARK:

A I'd like to turn now, to the Retrogressive-thaw flow slide. In Section 2, Part (ii) page 193, PAAG expresses concerns relating to the criteria for recognition of potentially troublesome slopes and the control measures that would be used in dealing with retrogressive-thaw flow slides.

Our response: a detailed

discussions of the factors influencing the development of retrogressive flow slides or for the headward enlargement of shallow failures and control measures is contained in the Response to the PAAG Requests for Supplementary Information, Appendix B, and in the NES report "Slope Stability in Permafrost Terrain" dated December 1974.

Dr. Morgenstern has illustrated several of these. I should note that in these discussions the term bi-modal flow has been use in favour of the term retrogressive thaw flow slide, however, both terms are synomonous.

PAAG concern regarding cut slopes in Section 2, part 4, page 194, the PAAG makes various comments in regard to cut clopes. Our response ,we are in agreement with PAAG concerning the geotechnical and geomorphological considerations discussed in section 2, part 4 page 194 and are aware of the potential problems involved. It should be noted that the geotechnical considerations in regard to the design of cuts are identical to those required in design of retrogressive thaw flow slides as discussed in part "D" above --

Q It was also illustrated by Dr. Morgenstern--

A Dr. Morgenstern illustrated several of these.

We wish to point out that the major conclusion reached in the report which is quoted by PAAG in the concern in section 2 part 4 page 194 and this is a report by Pufahl , that is P.U.F.A.H.L., et al -- that is E.T. A.L., 1974 --

Q That is not his name,that is others.

A That is what it means, Pufahl and others.

Observations on recent highway cuts in permafrost, environmental, social

program northern pipelines and this is a major conclusion, it reads in part and I am quoting that "The behaviour of cuts need not be a serious impediment to the routing of transportation arteries across permafrost." -- And we share that view.

I am turning now to the PAAG concern in "Creep of Ice-Rich Soils". PAAG states, page 194, that "The applicant has not considered the possible effect on the pipeline or other structures of long term down slope creep of frozen ice-rich soil ." Dr. Morgenstern made reference to this phenomena in the Great Bear River. OUr response: "There is no field evidence available which suggests that creep movements of engineering significance occur in permafrost slopes, However, we have underway detailed field, laboratory and office studies in order to substantiate the position that creep movements are not a limiting design concern. Should the findings of this study indicate that creep of permafrost slopes is a concern which must be accounted for in design, we are of the opinion that design methods can be developed to account for the creep and we would suggest as an example of such a method is the mechanical separation of pipe from the surrounding soil which can be achieved with relative ease. It is a simple and relatively straightforward procedure, to separate the pipe mechanically from the soil so that it is not dragged down the slope.

MR. GENEST: Sir, if I could move on now to --

MR. SCOTT: Before my friend proceeds, could I -- it seemed to me that we were doing beautifully until about three-quarters of an hour ago. I am going to do as I am sure the other participants, whether they have advisors or not, we are going to do the best we can in cross-examination to make this material comprehensible, but it seems to me that my friend is leaving rather a lot to us. He is preparing a record upon which the Commission is expected to ask which -- expected to act which he concedes he does not understand and which it seems to me that there is some obligation on him to attempt -- he may fail with the likes of me, to attempt to make some of this comprehensible. I frankly have great difficulty in understanding what in the last analysis is going to be done with a record in which it is generally conceded that nobody knows what he is talking about except the panel. Now, if it is impossible to make it comprehensible it seems to me it is pointless to adduce it. If it can be made comprehensible I hope that at some stage he would attempt to do so instead of simply leaving it and saying, well, you can cross-examine to your heart's content.

THE COMMISSIONER: Well, I think that you have made your point, Mr. Scott. The matter of C over V, I think did not strike a responsive chord around the room and I think that Mr. Genest is looking to you and your scientific advisors to cross-examine on that subject if C over V is not

the appropriate --

MR. SCOTT: Well, Mr. COmmissioner, respectively, the formula C over V obviously means nothing to me and I would gauge means nothing to Mr. Genest. I presume like all scientific formlae it is designed to exhibit some kind of relationship. Now, I would have thought that the panel would have been able to tell us in chief, because the obligation is on my friend to show his case, what relationship is intended by that, what the components of it are in brief so that we will have some understanding of what is intended. Now, he says, "Oh, well, others can do all that", and no doubt we can and may have to, but it seems to me that he is simply building a record that is incomprehensible and if there is no cross-examination upon it I do not know what is to be made of it.

THE COMMISSIONER: Mr. Scott, so that I understand the passages in the evidence of this panel that you feel are not sufficiently articulated, are you confining your remarks so far as this morning's presentation is concerned to the -- those pages where C over V appears?

MR. SCOTT: Mr. Commissioner, I thought that Dr. Slusarchuk and Dr. Morgenstern made a full effort to explain in general terms what was contemplated by their work and/their consultative services, and they did not carry me along with them at every point of the way but that is not their fault, that is my fault. They attempted to do it

fully, but beginning at page 8, we have -- and up until the present -- we have had the responses to the Assessment Group's concerns, I would have thought my friend would ask Dr. Clark, for example, for a -- in less technical language -- an analysis of the impact of the concern and where possible, and I would have thought it was possible in part -- an analysis of the response in language which makes the nature of the response a little more meaningful than he has done. He has now spent 20 minutes with Dr. Clark reading four pages and if anybody except the panel and the Commissioner in the room knows what he is talking about, I am not one of them.

MR. GENEST: Well, Mr. Commissioner, the only piece of evidence which I submit Mr. Scott's comments have application is that which appears on pages 9 and 10 --

MR. SCOTT: That might be correct --

MR. GENEST: -- of the filed summary. We have this problem, sir, that we are dealing in some aspects of this application, the engineering aspects, with concepts that can only be understood after a long period of academic training that are very difficult and it is very difficult to explain the theory of relativity to someone who is not versed in physics. It could take weeks. Now, I am able to do that if that is the desire of the Commission. I discussed that with Dr. Clark last night and that was the problem that we came up with,

that the concepts which have been expressed by the pipeline assessment group, who are scientifically knowledgeable and competent persons, are expressed in that language. They are concerned with the values, physical and mathematical concepts,which to the un-initiated,require a course of study to understand. Now --

THE COMMISSIONER: That was the overview --

MR. GENEST: That is right --

THE COMMISSIONER: I am not being facetious, that was of great assistance --

MR. GENEST: That is right. My conception of our duty to you, and I fully recognize that we must put before you an understandable case. That philosophy, it seems to me, is to be found in the spirit of your rulings, in the ancilliary statements that you made,where you required or you requested that there be made available to the Native people of the Mackenzie Valley broadcasts in their own language of the proceedings of this Inquiry.

Now, these problems are scientific problems. My conception of the role of Commission Counsel is that he has a staff to analyse the validity of these technical concerns. They are concerns that have been expressed and rightly expressed and I feel it is our duty to deal with, but they can only be dealt with on a scientific basis in scientific terms.

Now, I could ask Dr. Clark

to go over to page 9 and try and give us a lecture on the meaning of these terms which I am sure are readily understood by Mr. Scott's scientific advisors. If there is an attack on them we may have to come down to this, but surely if they are not controversial scientifically, it seems to me, sir, unless you direct otherwise, that it is good enough to deal with scientific issues by --in scientific language, which may not be understandable to me or to Mr. Scott or even, indeed to you. If controversy develops around them, then perhaps we have to try and reduce them to language more understandable to the layman. If you wish me to do that now, sir, I will go back to page 9 and I will do my best with the panel.

MR. SCOTT: Mr. Commissioner, could I give two examples. Mr. Genest first suggests that we are going to have to submit to a scientific lecture and while I am quite prepared for that, it seems to me it is not quite that complex. The two experts who have departed from the transcript, have been able, I think, to in concepts even I can manage, to explain some of the problems and to elucidate them, that is extremely useful and this is not a debate between scientists, it is a public hearing and I would have thought that that is the obligation of my friend, but two examples of what can be done for example, on page 11 the response quotes a summary -- a summary portion of a paper by Pufahl et al and says, "...the behaviour of the cuts need not be a serious impediment to the

routing of transportation arteries across permafrost", and that obviously is a conclusion that formed -- that is relied upon by the applicant. Well, you know, one asks the question why and I am quite certain that Dr. Morgenstern or whoever can tell us why that conclusion was achieved, what the characteristics of the cuts are that lead to that conclusion.

It will at least make that sentence explicable. On the following page we aretold :at the last sentence just because it's convenient, that an example of such a method dealing with creep, I gather is the mechanical separation of the pipe from the surrounding soil. Now I'm sure one member of the panel can tell us what is meant by that. I don't know what mechanical separation means.

MR. GENEST: Dr. Clark just did.

MR. SCOTT: I'm sorry.

MR. GENEST: What he was just reading, he added to that an explanation.

MR. SCOTT: Well then, I'm sorry, I didn't hear it, but if he did add it, it shows that by adding to the transcript as we go along we can get a fuller understanding of what is contemplated. I would hope that could be done.

MR. GENEST: Well, sir, I'm in your hands. I don't want to create a row or make anybody unhappy, and if you would like me to go back to page 9 and try my hand with Dr. Clark to see what we're getting at here, I'm quite willing to try. It seems to me, though, that we're dealing with detailed technical scientific concerns, the best way to deal with it is to put it on the record and the Commission counsel's own scientific advisors can then make a judgment on it.

THE COMMISSIONER: Well, I think that certainly in the first instance, Mr. Genest,

the obligation lies upon you to adduce evidence that makes these scientific propositions clear so far as that is possible to me, and to everybody else who is listening to you and to the witnesses that you are calling. I thought that that was your intention and I thought certainly this morning that you were succeeding in that endeavor because the presentations by Dr. Slusarchuk and Dr. Morgenstern were obviously designed to make this scientific material understandable to those of us who are not engineers.

Now you have lapsed from that laudable aim in dealing with the concerns related to slope stability that the Assessment Group raised at pages 9 and 10. I would be inclined for the time being to allow that to remain as an exception to the general rule and to allow you to proceed and if at the adjournment at least, if when we reconvene it is Mr. Scott's view that he still wishes those matters to be explained in the first instance by Dr. Clark or some other member of the panel, in the same way that Doctors Morgenstern and Slusarchuk explained their specialties earlier today, then I think I will require you to do that.

MR. GENEST: That's fine, sir.

THE COMMISSIONER: Maybe Dr. Clark isn't altogether prepared to do that at this stage, and I think it might be wise if we let Mr. Scott consider the matter at the adjournment and

then you and Dr. Clark could --

MR. GENEST: Fine, sir. I might add that we have two more presentations of the kind put forward by Dr. Morgenstern and Dr. Slusarchuk, one dealing with river crossings and the other with drainage and erosion control. Really I think that in this area, pages 9 and 10, with perhaps the little addition that Mr. Scott made on page 11 are the only problem areas in that regard.

THE COMMISSIONER: But let me make it clear that so far as I am concerned, I want the evidence adduced by any party to be understood. I want to understand it, and so far I have, I think, succeeded in that aim; but I want everybody else to understand it and because we have broadcasts in English and in the native languages, each day, this material should be understood by the broadcasters.

May I add that it seems to me that as a general rule in life, anyone who really knows what he's talking about can make himself understood in words of one syllable. You mentioned the theory of relativity. I saw Jacob Ramounski explain that on television a few months ago, in a way that led me to believe that I understood it at the time, and you know yourself, Mr. Genest, that if the lawyers here started talking about res ipso loquitor and caveat emptor, that you and I who believe in putting these things plainly as plain men would be concerned in that we would soon put a stop to it. Well, I think the same rule applies to any discipline and I'm glad Mr.

Scott raised this because I think we should try to proceed in that way throughout. But we'll leave C over V for the moment and press on to other matters.

MR. GENEST: All right,sir. May I ask then perhaps to cover one of Mr. Scott's concerns, taking back the panel to page 11 where we discussed cut slopes and the quotation from a report quoted by the Pipeline Assessment Group to the effect that the behaviour of cuts need not be a serious impediment to the routing of transportation arteries across permafrost.

Q Would you, Dr. Morgenstern or Dr. Clark, expand on that?

WITNESS MORGENSTERN: I'm one of the et al so that I have some knowledge of the report in detail. The study was a study to investigate all highway cuts in permafrost in Canada and Alaska that we could get access to. People went to the field for several months and investigated the terrain conditions, investigated how they were behaving, investigated some of the stabilization measures that have been implemented and I showed some of these in my presentations, and on the basis of that exposure to all of the cuts, and I think all the cuts of any significance, of any note, certainly all the cuts we find, that conclusion emerged. It was based then on as comprehensive a field program as could be put together.

Q And Dr. Clark, can I ask you to repeat for the benefit of Mr. Scott the technique of mechanical separation of pipe from

surrounding soil to account for creep? I don't refer to Mr. Scott by that last term.

(LAUGHTER)

WITNESS CLARK: What is intended here is that, first of all, as Dr. Morgenstern referred to in discussing creep, the stabilization measures themselves inhibit creep, such as a berm illustrated at the Great Bear River, but if we found that there was creep of engineering significance, it would be a procedure of placing a sleeve around the pipe so that the soil does not bond to the pipe. It would bond to the sleeve, and there would be down-slope movement perhaps of the soil, and it would carry the sleeve with it but it would not impart a stress to the pipe. Is that clear, sir?

MR. SCOTT: No.

A Well, let's start with the pipe itself. Now before the backfill is placed, in fact before the pipe is placed, we have put a thin shell around it and there would be an anular space between the pipeline and the shell and that could be filled with a lubricant, any of the common lubricants, so that as that shell moves with the soil, the pipe stays behind. The soil does not have direct contact to the pipe, it's mechanically separated from the pipe so that it wouldn't transfer loads to the pipe.

If you can visualize one ring consisting of the pipe, and an outer ring con-

sisting of this shell and it's this outer ring that's in contact with the soil rather than the pipe. If that wanted to move, it could move over and down the pipe and the pipe would remain where it is, without carrying any load from the soil.

COMMISSIONER: Well, the reason that I didn't understand you the first time was that the explanation was so simple. I was looking for something more difficult.

MR.GENEST: I may say, sir, that I don't want to leave Mr. Scott with any bad feeling, that in my view at least, Commission counsel perhaps has a different role here than others, he's here to help and if there are instances, where in his view something isn't clear, I would certainly not object to an interjection by him to help clear up a matter that may have been explained to me the night before and I may have assumed too much knowledge, and I would treat his intervention much as I treat yours, sir. They're welcome because they help to clarify issues. So I don't want to give you the impression that I'm on my feet with my fists up.

THE COMMISSIONER: I wish to say, Dr. Clark, for the benefit of you and your colleagues, this Inquiry will be going into all of these communities, including, for instance, Fort Norman, and the people there will express to us whatever concern they have about that river crossing near to their village, and we want to be able to consider what they have to say to us in the light of what you

have said. We also want the broadcaster who broadcasts in the language that the people speak at Fort Norman, to be able to inform them on the basis of what he has heard here, inform them of the essence, so to speak, of what you and your colleagues have said. That's why we're stopping and trying to sort this out today. It's not that -- I trust you and your colleagues realize it's no reflection on you and your colleagues in any way. This is an Inquiry which is seeking to inform the people throughout this valley of what is being said here, and that isn't easy. Well, carry on then.

MR. GENEST: Thank you, sir.

Q I'd like to move along to the section now on river crossings, Dr. Clark.

A This is one area, sir, where a number of responses have been submitted to these concerns. Up to now, I have been trying to add where possible supplemental response, if you like, that have come out since we received the report. We first received the questions and we responded to those questions. Then we received the report, and we identified certain areas there that hadn't been asked of us before, and we have throughout here tried to respond to some of the other issues.

Before leaving our old friend, C sub V, we are prepared to attempt to put this in a form that can be simply understood, and we'll do so if required by yourself and Mr. Genest.

There are, throughout the remainder of this, I don't think too many more areas that are that technical that they, supplemented by what we are trying to do with our slide presentation to make it more comprehensible,that should be perhaps as incomprehensible as C sub V is. However, when the question posed to us concerned C sub V, we felt we had to talk about C sub V, and to sit and listen to that, sir, I'm sure the tediousness of that could only be exceeded by sitting and reading it.

With respect to river crossings, the first concern relates to sediment movement, concerns expressed about the effect of temporary increase in suspended sediment resulting from construction activities. This was one that came out

in the questions and it's addressed, as far as possible, in response to question 42, paragraph 1, of the request for supplementary information. We believe that with the careful design and construction control the installation of river and stream crossings should not have a serious adverse effect on the stream environment.

Q Are we going to be dealing with these design --

A Yes sir, Dr. Hollingshead and Dr. Cooper will be presenting a slide illustrated discussion of many of these aspects that I'm going to present our response to the concerns beforehand.

Next is dispersal of toxic substances, PAAG is concerned that other pollutants such as petrol, oil and lubricants, warm water, methanol, may enter the river system during construction. This concern is answered by a response to question 40 and 53 of those requests for supplementary information.

Q Well, perhaps we could turn to those responses, 40, stated as background, if I could just summarize it, that test fluids, the waste test fluids could cause danger and there is some information required to the effect that you're asked to provide information of the probable residues in the pipeline test fluids, the locations and times of year when disposal would occur, the procedures to be used to lower the content of such residues to acceptable levels and the precautions that are planned

so that the volumes of fluid discharged into a water course would not harm fish or other aquatic organisms. The answer appears at page 40-1, could you summarize it for us, Dr. Clark, or is that dangerous?

A Well, it's slightly over a page and I'm sure it has been read by those that have expressed this concern. It would be dangerous, in any event, to summarize these in a few succinct words, but with respect to warm water testing, the last paragraph, the volume per se of water is not expected to be harmful to any aquatic life. It may be possible in some cases that water which is deficient in oxygen must be disposed of. In any event or in such event, applicant proposes to aerate by spraying at the disposal site, and what this means is that the water when it is disposed of would be broken up into a fine spray, so that when it goes through the air it picks up oxygen and would not be deficient in oxygen by the time it reaches the water course.

Q Then we have a concern with the water freeze depressant mixture. That, I understand is methanol, is it?

A Yes sir, methanol.

Q That's the anti-freeze that we propose to use?

A Yes.

Q And that is for the purpose -- we're getting ahead of ourselves but that's going to be used before the pipeline goes into operation?

A That's used for testing of the pipe.

Q To test its integrity?

A Yes sir.

Q That's a short answer, perhaps you could read it.

MR. SCOTT: If I may interrupt, Mr. Genest, I take it that these two subject will be dealt with also in Phase 2?

MR. GENEST: Yes.

MR. SCOTT: It comes as some surprise to us that they dealt with it here, and I presume he will be producing a panel at Phase 2 that will be able to deal with it.

MR. GENEST: There's no pleasing him today.

A As I pointed out at the outset, Mr. Genest, many of these things do fall in Phase 2. I think I said that --

Q Yes, you did.

A -- back at page 1. We have difficulty, sir, I'm sure you will appreciate it, drawing a distinct line between Phase 1 and Phase 2. These are areas, all of these questions or responses that I listed at the outset, there was some geotechnical input, geotechnical in the sense that it involved our river engineers, our slope stability, drainage and erosion control people and so on.

Q Yes, there will be some more discussion of that with the next panel when metallurgy will

be discussed, testing procedures. Perhaps I will leave out reading into the record that answer. That brings us to channel constriction, Dr. Clark.

A PAAG is concerned that the proposed construction work pads will restrict channel cross-sections and increase flow velocity.

Q Before you go to the response, could you explain a little more what a channel restriction is? What are the proposed construction work pads that we're talking about?

A Well, at river crossings, for example we looked at the Great Bear crossing, there would be a temporary pad built out on the bottom for equipment, storage, pipe and so on, or movement of pipe, and it would be -- the pipeline would be laid across the river and this pad that is there is probably constructed of gravel, gravel incidentally which would probably be used for bank protection afterwards, or stabilization, if required. That is removed from the river after construction. Dr. Hollingshead will be able to illustrate some of these features in his discussion on slides, which I believe should be self-evident.

Q Now your response says -- refers us to the answer to question 44.

A That's right, sir.

Q And where the information was required was to provide evidence that temporary structures described in the above-mentioned section

-- which were the work pads you just referred to. -- would have no serious deterrent effects upon fish migrations and would not induce a long term reduction in fish populations.

A Yes sir, and we've attempted to identify, for example, the length of work pad or length of b erm,construction berm, what the discharge is, how the increase -- how the discharge or flow velocity would be increased for the period that that berm is in there, and this also had input from the fish biologists and again covers both Phase 1 and Phase 2 areas.

Perhaps Dr. Hollingshead could have some comments on that.

WITNESS HOLLINGSHEAD: Yes, the reason I think it might be well to speak to this problem now is I'm not sure I have the slide that can show you readily when we get to that stage. It was because of a concern for the stability of the slope which you are looking at on the scene when Dr. Morgenstern was addressing the Great Bear slope, potential slope problems there. We decided or considered it would be a good idea to minimize the cutting into that slope, An alternative mode of installing the crossing, because the channel is very shallow on the opposite side for about half the way across the river, six to 800 feet, it's very shallow, in the order of five feet, because of that shallow depth of water, it was considered reasonable, feasible

to install the pipe at that location from a work berm or work pad which would in effect stick out into the river. Our fish biologist friends looked at this and were somewhat concerned about what that might do to the velocities in the river, and the question which is answered, that is question No. 44, the answer in this orange book, simply illustrates that the increases in velocity and in stage, that is river level created by this constriction in the river, really are not significant and in fact at the Great Bear would increase the velocities in the order of some 20% to something like five feet per second, and that velocity, of course, would only extend over that reach of river which is in the immediate vicinity of crossing.

Q We'll hear from the fish consultant on how that affects fish. Sir, I'd like to move on to a Pipeline Assessment Group concern with reference to icings.

WITNESS CLARK: Yes sir. The PAAG is concerned that the pipeline construction and operation activities may induce local new icings at minor river crossings.

THE COMMISSIONER: Excuse me, just so we understand each other, an icing is an ice jam, is that --

A No sir, this is where water, for instance, flowing in the bed of the river, would be forced by some reason to the surface and accumulates on top of the normal river ice.

Q Yes, that's right. Somebody did say that, excuse me.

A Our response to ~~t~~this concern, it's agreed that operation of the chilled pipeline by itself could induce new icings at some minor river crossings. These in themselves are not viewed to be a serious problem either to the pipeline or to the environment.

However, if the creation of such an icing will seriously deplete the winter water supply to fish overwintering area, measures can be taken to insure that the ground water continues to pass through the frost bulb around the pipe.

Q How do you do that, Dr. Clark?

A If I could set the scene where we have a river crossing with a relatively shallow bed of gravel which is carrying water down stream to overwintering areas and when we put a pipeline in that gravel and the pipeline wants to freeze off the gravel, the way that we propose to deal with this is to put in a -- in simple terms -- a culvert system, that would pick water upstream out of the zone of influence, carry it through the frozen bulb in an insulated pipe and redistribute it downstream, immediately downstream from the pipe so that the water that would normally be blocked off and might come to the surface and create an icing, would be collected here on the upstream side, conducted through the zone influence by frost where it would not freeze because of the insulation and redeposit it on the downstream side.

At the present time there are only a few known overwintering areas located downstream of a pipeline crossing.

The next aspect of this, the concern for accelerated lateral migration --

Q What is that --?

A -- is recognized. This is

the increased widening of a river or movement of a river bank which I believe will be clearly illustrated by Dr. Hollingshead and Dr. Cooper.

Now, in the final design we allow for some accelerated erosion to occur without endangering the pipeline. This means that sag points that we defined yesterday are put back so that if lateral migration does occur, they will not be exposed. If, however, the lateral migration would appear to be excessive, there are adequate control measures to put in to inhibit it and one of these would be reinforcing the bank with gravel or rip-rap as we discussed before.

The next PAAG concern deals with local bed scour. The PAAG expresses concern about the accuracy and reliability of scour predictions. We appreciate this concern and recognize that given the present state of knowledge a high level of engineering judgment is required in making estimates of potential scour depth. However as a result of recent studies initiated by this project and the Aleyeska project, significant advances have been made, particularly with respect to braided gravel rivers which are prevalent along the proposed route and without going into all of these, sir, these will also be illustrated by Dr. Cooper.

PAAG makes reference to a figure shown in one of the exhibits, section 14.D.N43-2. It is true that this figure has not been and would not be used for design purposes in all

instances. The rationale and procedure for calculating depth of scour under open water conditions are detailed in the response to questions 36 and 37 of the request for supplementary information.

Q Now, is this going to be dealt with by --

A Yes, sir, this willbe included in the slide presentation and discussion.

Q All right, so we do not need to go to the specific responses at this time.

A I believe it would be covered in a clear way.

Q Right.

A Now, although preliminary designs have been based on the potential for scour under open water conditions, it is recognized that local river bed scour associated with the formation and the release of a severe ice jam is an important consideration in the design of a buried river crossing and I can assure you that we will see some exceptionally interesting slides on the development of ice jams, sir.

Now, this is particularly true for the crossing of the Mackenzie River, with a potential depth and extent of bed scour has been given detailed study in both the field and in office. For the most severe ice jamming conditions that are considered possible, these studies indicate that safe crossings can be constructed although a comparatively deep burial will be required. Dr.

Cooper will illustrate this.

Now, Mr. Commissioner, you asked about permafrost under the rivers, there was a soils drilling program at major river crossings being conducted at about the time of the application. The information was not available in time to put on the drawings that were submitted with the application. The results of this program, including the logs of the holes which were drilled into the channel bed are shown on the design drawings submitted with the east of Fort Simpson amendments, in other words, we took advantage of this opportunity to update those other drawings by including the soil profiles. Now, PAAG also expressed concerns relative to the Burnt Island and Liard crossings and the recent route revision eliminates both of these crossings.

The next concern relates to general degradation of the bed which may result from pipeline related activities and again, Dr. Cooper will demonstrate what is meant by general degradation. We recognize that this occurs in some circumstances. This is fully considered as part of the regime analysis which is an integral part of the crossing design process. --

Q What does that mean, Dr. Clark?

A In analysing the regime, one takes into account all of the factors that affect the nature of the flow of a river through any given stretch. Such factors as how much

bed material can it carry, how much suspended material can it carry, how much scour and so on.

Q This you do on a river by river basis as you are doing your final design?

A Yes, sir.

And examples of design will be illustrated. There is no intention of course of permitting pipeline related activities to upset the regime of a river or endanger the security of a crossing through general bed degradation. IN other words, I am saying that this is a very important consideration in design and will be incorporated into the design. It cannot tolerate general bed degradation.

NOw, the next concern relates to lateral migration of the channel and it has been pointed out that this can expose or wash out the pipe. We also recognize that this is a natural process and we have taken this into account in design. WE would also make reference to thermal niching -- N.I.C.H.I.N.G., this is the melting out of soil below the bank and creating a niche in the bank leading in some cases to what Dr. Morgenstern described as fall. Dr. Cooper will be addressing this process. In locating the sag points, however, in the design, they are located back into the banks or a sufficient distance so that they will be unaffected by such processes or the banks of the river are protected from exposure to these mechanisms by again rip-rap or a bank armouring as we refer to it.

Now, the channel banks will be rebuilt and stabilized and there is a design illustrated for the first river crossing in the response to question 42. "Bank armouring and river training works will be used where necessary to ensure that the pipeline does not become exposed."

The next is part of a concern or an observation made by PAAG, as stated by PAAG, we have recognized the potential --

Q That is on channelization --

A On channelization.

Q What is that?

A Channelization is a redirection of the river to flow, for instance, along the pipeline where it crossings a river, for example, in a braided stream, that one of the channels may redirect itself along the pipeline and the design must insure that this does not happen.

Q What are the solutions that you proposed that were referred to by the Pipeline Assessment Group?

A These are given in some detail in volumes II, III and IV of the reference book of water crossings and in the Blench report which is included in Appendix "C" on design criteria.

Q Without going into each and everyone of them could you describe them briefly.

A Dr. Cooper can amplify

on some of these.

WITNESS COOPER:

A As Dr. Clark mentioned, channelization is normally a problem where we get channels shifting from their existing course to right along the pipeline right-of-way and flowing down the pipeline right-of-way. In that respect we get the potential for scour over a considerable length of the pipeline. Now, the most common method for eliminating this -- eliminating the possibility is to make your river crossings essentially at right angles to the flow of the river. This is being done in almost all instances on this pipeline as opposed to, for example, the Aleyska Pipeline, which because of their route they had to parallel rivers. The only case on this line where we are paralleling rivers is in Alaska on the Canning River where we have to go right down that valley, but in all cases in Canada, we are crossing the river system essentially at right angles. Consequently the flow is going directly across the pipeline and there is no slope advantage for it to flow down the pipeline.

Where there might be a slight angle to a floodplain or there might be some high water channels within a floodplain, channels could develop over the pipeline in a region where it would possibly not be deeply buried. Then we would employ one of several possible river training structures to prevent the channels from shifting to these high water areas. Now, those are essentially the two methods

that are employed on this route.

Q What are river training structures, Dr. Cooper?

A Well, I think the best way to illustrate with the example that I gave if we can visualize a braided river and we have got an active channel area that, of course, we are crossing in a deep bury mode. We then have some floodplains which may contain one or two high water channels. Now we would have to look at the possibility of flow diverting into those high water channels and channelizing across the pipeline and essentially scouring them out. We may choose in design to block off these channels and we would put what is effectively a low rock weir in them to prevent flow from developing in those channels.

WITNESS CLARK: I might add, sir, The channels, the high water channels that he's talking about, only carry water during the flood stage and they could be kept from carrying water that would be -- that could scour and deepen that channel during that season.

Q Thank you. You then speak of a concern relating to the stability of bank approaches.

A Yes sir, and this I believe has been covered in sufficient detail on the presentation that Dr. Morgenstern gave on slope stability and in other answers where we talked about one of the now well-known parameters.

Q Moving on then to the report, to the concern expressed in the Pipeline Assessment Group Report, chapter 8.8 entitled:

"Impact in valleys."

What are your comments there?

A Yes, we can deal with this now, sir. However, it was our intent to have Dr. Hollingshead and Dr. Cooper illustrate these features that we have briefly discussed on the response to concerns of river crossings, but their illustrations, I'm sure, will run substantially into the afternoon but we can move onto this relatively short response to impact in valleys, if you would wish to.

Q All right, well why don't we do that and then we'll illustrate it later, perhaps, Mr. Commissioner, although we're five minutes or so short of the time of rising, we are

getting into our slides very shortly after this and it might be convenient to break after this brief statement, if that is satisfactory to my friends.

These slide shows are hard to interrupt.

THE COMMISSIONER: Yes. Well, you're suggesting we adjourn now until this afternoon?

MR. GENEST: I'm suggesting tha~~t~~ perhaps Dr. Clark could deal with page 18, the impact on valleys, and then we rise.

THE COMMISSIONER: Yes, certainly.Well go ahead then, Dr. Clark.

WITNESS CLARK: Well, with respect to pipeline crossing locations, sir, virtually all of the principles mentioned by the PAAG in discussing the location of pipeline crossings are accepted as good principles of geotechnical and river engineering, and they have been considered in the location of the proposed route. There are, of course, other factors -- line length, environmental, social factors, for example, which play an important part in the final selection, and these -- the route selection per se has already been discussed. Our problem is giving an area to design a crossing or select at that river the best crossings. Now crossings close to the proposed highway would be desirable for reasons mentioned, that is for ease of access. However, points where the separation is less than 1,000 feet from the highway should be kept to a minimum and the nature of

the terrain may in some instances dictate a much greater separation. PAAG mentioned specifically the Thunder River. Although the Thunder River crossing is not considered to be a poor one, it will be studied further as a candidate for possible re-location. I mentioned yesterday that of the 200 or so river crossings in Canada, there are approximately eight now where we feel that there will be a possibility of some minor re-location and there is one where there is a greater one, and this is the Great Bear River. Now while the level of the terrain sensitivity may be reduced by re-locating the crossing upstream near the Mackenzie Highway, this is relative to the Thunder River, this significantly increases the pipeline mileage. Re-location of the Great Bear crossing is being actively investigated at the present time. I mentioned yesterday we have crews in the field now that are drilling and sampling for testing, this will provide us with the detailed analysis of the slope along the lines followed through by Dr. Morgenstern this morning, and it would then be a case of whether or not it is more economical to construct the slope and stabilize it, or perhaps to move to another slope. Our philosophy in locating river crossings and crossing slopes is not to cross old slide features. We feel that it is easier to deal with a slope that hasn't failed in its geologic past, than to cross one where it has. There are, however, many slopes that have failed at some period in their geologic history that may well now be stable and would

be unaffected by the pipeline. This is the case at the Great Bear. There are old slide features along there that will be investigated to see if it would be preferential from a stability point of view.

MR. GENEST:

Sir, I had hoped to finish this morning. I have perhaps an hour, I wouldn't think more, depending on what we do with C sub V tomorrow. So if we could rise now?

Oh, perhaps before we do, sir, I can deal with a matter that was raised by Mr. Anthony during his cross-examination of the first panel, and that relates to the production by Arctic Gas of copies of Minutes of two meetings that were held between certain personnel of Arctic Gas, including many others, and certain members of the government, at least officials in the various departments of the government. I examined the Minutes that we received, sir, they were marked "Confidential" and my understanding of the -- they were prepared by the government representatives at these meetings so I felt it my obligation to consult with them. I am informed by the government that they do not choose to, in respect of these documents, to assert any claim to privilege or assert any objection to their production. They do not wish this to prejudice any production -- their position on the production of any other documents of this nature, but as far as these two documents are concerned, they have no objection to my producing them and of course I have done, and I have here for MR.

Anthony two sets of minutes, the minutes of the meeting of the Mackenzie Highway discussions held May 5, 1972 with a very large number of participants, and minutes of a meeting of something called the Mackenzie Highway Sub-Committee, held on May 18, 1972 in Ottawa, and I can let Mr. Anthony have these.

THE COMMISSIONER: Well, I think they should be marked.

MR. GENEST: If it's the wish of the Commissioner.

THE COMMISSIONER: Mr. Scott, should they be marked?

MR. SCOTT: I'll leave it to Messrs. Genest and Anthony. I have no --

MR. GENEST: We have been asked to produce them. I can make them available to Mr. Anthony if he wants to submit them in evidence. Surely that should be his decision.

MR. ANTHONY: Well, I undertake to file them, either now, which may be more convenient, or at the time their initial interjection. Perhaps they could go in now.

THE COMMISSIONER: I think they should go in now. There's a reason for that, Mr. Genest. This is a public Inquiry and what you've said will no doubt arouse a certain amount of interest, and I would just as soon that they were marked as Exhibits, on the public record, and then that's that.

MR. GENEST: Can I hand them up to the secretary?

(MINUTES OF MEETING, MAY 5, 1972 MARKED EXHIBIT 79)

(MINUTES OF MEETING, MAY 18, 1972 MARKED EXHIBIT 80)

MR. SCOTT: Perhaps the Minutes of May 5 could be Exhibit 79, and the Minutes of May 18 will be Exhibit 80.

THE COMMISSIONER: Three o'clock?

MR. SCOTT: Mr. Commissioner, the special witness that we were contemplating having this afternoon is not going to be present so it won't be necessary to interrupt the proceedings. May I suggest that we should meet at nine tomorrow? I recognize that there is some anxiety to get through these matters, and we propose to take up at the Counsel Meeting tonight whether there should be an alteration of the sitting hours. Before doing that and obtaining the consensus of counsel, I would be reluctant to recommend any change to you, As you may have observed, the evidence is very technical and to use a water percolation phrase, I think, it has to percolate through our heads so that (a) we can understand it, and (b) so we can prepare ourselves to answer questions about it.

THE COMMISSIONER: Yes.

MR. SCOTT: I think if I may respectfully say so, it might be advisable to adhere to the hours that have been fixed, unless there is any violent disagreement here, until the various counsel have had an opportunity to make comment about them.

THE COMMISSIONER: Well, we'll leave it at that for now, but at the Counsel Meeting tonight you will be discussing ways of ensuring that

we complete the examination of this panel this week?

MR. SCOTT: I don't see any possibility that it can be completed this week. We will make every effort to do so but one of the difficulties -- and it relates to the second question -- is that of course . . for example, in dealing with C to the V power, or whatever it is, I have available technical resources which if they have time, can fully explain even to me the impact of that formula or whether it has any impact. I presume the other counsel who have not been heard from have the same facilities. The utilization of those facilities require some little time, and it doesn't seem to me that it can -- that there should therefore be a change in sitting hours until the various counsel have been polled to see how that will advance or handicap their presentations to you.

MR. ANTHONY:

Mr. Commissioner, if I may be permitted one comment. That if it is the desire of the Commission that we have extra sittings this week to pursue the matter, might I suggest that this take place now while the evidence in chief is being presented rather than later on when the time to prepare the cross examination is more critical. And if there was a desire to institute extra sittings, I for one, would suggest that perhaps we could go this afternoon to allow the evidence in chief to go in rather than to put in extra sittings when we need the time to prepare cross examination

MR. SCOTT:

Well as I say, Mr. Commissioner, if that's the consenus of counsel, I oould have no objection to it, if that's the view.

THE COMMISSIONER:

Well, how many more hours of evidence in chief would there likely be Mr. Genest?

MR. GENEST:

Well, as I said sir, depending on what we do with "c" to the "v", I don't anticipate more than an hour. Perhaps I can poll my panel on it. Is that what you would say Dr. Clark?

WITNESS CLARK:

A It would be an hour to two hours, sir.

MR. GENEST:

An hour to two hours.

Then I'm in your hands, I have no objection to carrying on this afternoon.

MR. BAYLY:

I would suggest we follow Mr. Scott's recommendation, because I think it is something that probably should be discussed by Counsel, rather than each one of us getting up and putting this sort of thing on the record.

THE COMMISSIONER:

Well, I guess we'll leave it to Counsel. It sounds as though we are in pretty good shape, so we will adjourn until nine o'clock tomorrow morning.

(PROCEEDING ADJOURNED TO MARCH 19, 1975)

MACKENZIE VALLEY PIPELINE INQUIRY

IN THE MATTER OF AN APPLICATION BY CANADIAN ARCTIC GAS PIPELINE LIMITED FOR A RIGHT-OF-WAY THAT MIGHT BE GRANTED ACROSS CROWN LANDS WITHIN THE YUKON TERRITORY AND THE NORTHWEST TERRITORIES FOR THE PURPOSE OF THE PROPOSED MACKENZIE VALLEY PIPELINE

and

IN THE MATTER OF THE SOCIAL, ENVIRONMENTAL AND ECONOMIC IMPACT REGIONALLY OF THE CONSTRUCTION, OPERATION AND SUBSEQUENT ABANDONMENT OF THE ABOVE PROPOSED PIPELINE

(Before the Honourable Mr.Justice Berger,Commissioner)

Yellowknife, N.W.T.

March 19, 1975.

PROCEEDINGS AT INQUIRY

VOLUME XXI

ALLWEST REPORTING LTD.
4299 CANADA WAY,
BURNABY 2, B.C.

APPEARANCES:

Mr. Ian G. Scott, Q.C. Mr. Stephen T. Goudge, Mr. Alick Ryder and Mr. Ian Roland	for Mackenzie Valley Pipeline Enquiry;
Mr. Pierre Genest, Q.C. Mr. Jack Marshall, Mr. Darryl Carter, and Mr. John Steeves	for Canadian Arctic Gas Pipeline Limited;
Mr. Reginald Gibbs Q.C. Mr. Alan Hollingworth	for Foothills Pipelines Ltd.;
Mr. Russell Anthony, Prof. Alastair Lucas & Dr. Andrew Thompson	for Canadian Arctic Resources Committee;
Mr. Glen W. Bell and Mr. Gerry Sutton	for Northwest Territories Indian Brotherhood and Metis Association of the Northwest Territories;
Mr. John U. Bayly	for Inuit Tapirisat of Canada and the Committee for Original Peoples' Entitlement;
Mr. Ron Veale and Mr. Allan Luke	for Yukon Native Brotherhood;
Mr. Carson H. Templeton	for Environment Protection Board;
Mr. David Reesor	for Northwest Territories Association of Municipalities
Mr. Murray Sigler	Northwest Territories Chamber of Commerce

I N D E X

Yellowknife, N.W.T.
March 19, 1975.

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

MR. SCOTT: Mr. Commissioner, Mr. Mercredi of Fort Simpson is here and I propose, if you permit -- I've discussed this with him -- that we could hear him briefly at a quarter to one, if that will be satisfactory to you.

THE COMMISSIONER: That will be fine.

MR. GENEST: Mr. Commissioner, during the evidence in chief of this -- the beginning of the evidence in chief of this panel, sir, you expressed some interest in the experience or the knowledge that we have been able to gain from visits to Russia or contacts with Russian scientists, and I have available Mr. Don Fielder from the staff of Canadian Arctic Gas, who has returned from a trip to Russia in December of 1974. He could assist in that regard either now or perhaps when the construction panel is called, and in that respect I'm in your hands, sir.

THE COMMISSIONER: Mr. Scott?

MR. SCOTT: Mr. Commissioner, Mr. Genest was good enough to mention this yesterday. I would propose that Mr. Genest be asked in the usual way to let us have a summary of what he's going to say. I have no particular objection to calling him out of place, if it's a matter of very great convenience; but it may be that without having a summary, we are not able to judge whether it will be possible

to conduct a cross-examination.

MR. GENEST: If it's not a matter of convenience, it would, I think, be just as convenient to have him come back.

MR. SCOTT: Well, may I suggest then that if the other counsel have no objection, that in due course Mr. Genest should let us have a summary? The reason I'm concerned about it is that there is a government report that touches this matter and in the course of preparation and it would be useful to hear Mr. Fielder when that report's available, I think.

It seems to me it would appropriately be part of the construction phase, which is just around the corner.

MR. GENEST: That's fine, sir.

MR. SCOTT: Mr. Commissioner, can I raise one other matter, Mr. Pelton of our staff has written to Arctic Gas in January, asking for a number of reports, many of which relate to this phase. Some 20 of them, I think, or more than 20, have not been provided as yet, and I would wonder, without reading out all the numbers of those reports, at this stage if I could have Mr. Genest's undertaking to see that those reports are available to us before cross-examination occurs. Perhaps I should give you the numbers. The reports number 19, 51, 52, 70, 77,81, 84, 87,88, 89, 90, 91, 94 --

MR. GENEST: Slow down a little, Mr. Scott.

MR. SCOTT: Well, I'll give you the list. I'm just reading it into the record. 130, 132, 133, 139, 140, 149, 161, 203, 215, 240, 298, 300, 301, 312, 319, 324, 325, 327, 335, 336, 348, 430, 431, 442, 443, 444, 445, 446. Now we're prepared to pay to have these copied in manageable size or attend where they may be inspected, or do whatever is necessary to get access to these at the earliest possible time, and I'd be grateful for my friend's assistance.

MR. ANTHONY: I would like to direct a comment before we proceed, since Mr. --

THE COMMISSIONER: Excuse me, Mr. Anthony, I can hear you but the reporters may want it on tape so they can get an accurate record.

MR. ANTHONY: Mr. Commissioner, I think that Mr. Scott is anxious to obtain co-operation this morning. I wonder if I may direct a comment to him and request the co-operation of Commission counsel? Back in February 18, 1975, I directed a letter to Mr. Scott as the counsel responsible for production of documents on behalf of the Government of Canada, and directing his attention in particular to the government list, which excluded the reports of such bodies as the National Energy Board, The Canadian Transport Commission, The Northern Transportation Company Limited., and I'm wondering if Mr. Scott would be able to respond to that request and indicate what position, if any, the government has taken with respect to our request directed to him?

MR. SCOTT: I understand , Mr.

Commissioner, and indeed I've communicated this to Mr. Anthony, but I should report for the record that the government has taken the position that those reports are not covered by the preliminary rulings, as they are reports of independent agencies. I suggested to Mr. Anthony, I presumed he has written to these agencies asking for what reports they have. If he fails to obtain results in that fashion, I'll be happy to discuss with him what his remedies are, which are also provided in the rulings, and he may want to take advantage of one of those remedies as we go along.

MR. ANTHONY: To perhaps assist in moving the matter along, I might say that we have contacted various of these bodies privately, shall we say, and have obtained generally refusals. We have been unable to obtain any official refusal or any statement on an official capacity, and once I have that perhaps that would be the appropriate time to return to Mr. Scott and to this Commission with any further requests.

MR. GENEST: Sir, I wonder if might have a crack, as I said this morning, at C sub V which would be a return to page 9 of the summary of evidence which dealt with a concern in the Pipeline Assessment Group listed in Section 2, part 2, page 193 of their report, relating to the method of analysis that the applicant considers applicable to shallow slope failures.

JOHN IVOR CLARK
GARRY WOOD HOLLINGSHEAD
EDWARD CHARLES McROBERTS
WILLIAM ALEXANDER SLUSARCHUK
NORMAN REUBEN MORGENSTERN
RICHARD H. COOPER
R.M. HARDY
GUY LESLIE WILLIAMS, Resumed:

DIRECT EXAMINATION BY MR. GENEST CONTINUED:

I would like to ask Dr. Morgenstern to try and illustrate this in less technical language than was provided yesterday.

WITNESS MORGENSTERN:

A I sympathize with my colleague, Dr. Clark, yesterday C sub V is a difficult concept to explain very briefly and I hope, sir, you will bear with me as I take you through some of the fundamentals of soil mechanics.

The coefficient of consolidation is a parameter that reflects the relative interaction of the deformation of soil and the ability of water to get out of it. As water is squeezed out of the soil under load, the soil deforms and this coefficient that we are talking about describes the interaction of these processes.

Let's begin first of all with imagining a dry soil without any water in it and we are going to represent it by the simply mechanical model of a spring. Imagine a rather tightly fitting piston and we put a load on that piston. There is no water in the system here and the spring will deform and carry that load.

Soils are frictional materials. The origin of their strength resides in friction between particles. As the skeleton of the soil takes more load, deforming and therefore taking load, so the strength of the soil increases.

Now, if we imagine that we fill this cavity with water, the interaction of the

skeleton now pays attention, takes account of the fact that the cavity is full of water. When we put a load on the piston, instead of the spring deforming, in fact, the water in this cavity will carry the load. We now are simulating a soil saturated with water or a soil recently thawed so that the ice has been transformed to water and the over burden pressure, the load above our recently thawed soil is being transformed to the water, is being carried by the water. The skeleton will not deform because the water is stiffer than the skeleton and it will carry the load. Hence, we transfer no load to the skeleton and it is not strengthened through the frictional process.

Now, this is not altogether an appropriate representation of the soil because in this model with the tightly fitting piston, the water cannot get out. A better representation would be to draw a hole, or to sketch a hole in this piston that illustrates the porosity or the capability of water to drain out of the porous soil under load.

Now, let us imagine that we load our recently thawed soil. At the outset the load is carried by the water and not by the skeleton of the soil. The water generates pressure in response to the load. The pressure then will squeeze water out of the little cavity which represents the hydraulic conductivity or permeability or capability of a porous material to transfer water under pressure.

As the water is squeezed out

of the soil, there is a transfer of load from the water to the skeleton of the soil. Alternately the pressure in the water will completely dissipate, a certain amount of fluid will be squeezed out, the soil skeleton will take all of the load and it will consolidate and deform.

Now, in this mechanical model, we have introduced two physical concepts or two physical parameters of soil. ONe is the soil characteristic that this little hole is modelling, the hydraulic conductivity that we denote in our symbols by a little "k". The other characteristic of the soil that we have introduced is the deformability of the spring, the soil is of course not a spring, but it deforms rather as a spring might deform and we denote -- in our symbols -- we denote the stiffness or deformability of the spring by a symbol m_v. The coefficient of the consolidation which controls, for a given thaw situation, the amount of water pressure generated here and the subsequent movement of water out of the soil is the ratio or it is proportionate to the ratio of these two things: coefficient of consolidation is eqal to $\frac{k}{m_v}$ and the density of water enters into this, but that is just a dimensional issue. These are the two physical ideas: the permeability or capability of water to flow under a gradient through the soil and the compliance, deformation of the soil.

The interaction of these two things govern how long the water pressure will stay

high or alternatively how long the soil will stay weak, because if we sustain high water pressures for a long time we do not transfer much load to the soil and it will stay rather weak for a long time following thaw.

So that this parameter governs that process. Now the point that we were addressing in the reply to the concern is that the concern did a calculation that said that if you reduce this number by an order of magnitude, a factor of 10, from the values that we have cited in typical calculations, the maintenance of high water pressures in the thawed soil would be sustained for a much longer time than we have suggested, and the soil will accordingly be weaker. The strength of the soil under these thawing and consolidating conditions are used in the analytical procedures that we adopt for stability calculations. Therefore, if you use a much reduced value of the co-efficient of consolidation, you would demonstrate that slopes that we might have thought stable become unstable.

The response that is addressed here is that the argument really should be converted the other way, that the value of this co-efficient that we cite is certainly the lowest or most conservative value of our experience, and there is evidence for thawed soils, experiments carried out by work done for Aleyeska, the one set of data, other experiments are cited in supporting reports, that really a freshly thawed soil has a lot of cracks in it. We saw that the ice formed in lenses,when these lenses are thawed they leave preferred paths that allow ready escape of water. This augments or increases the size of that hole, or increases the magnitude of this No. K, the hydraulic conductivity of the soil,

and the point that we make is really if one were reflecting more characteristically the properties of freshly thawed ground, the argument should be reversed but the co-efficient of consolidation would really be higher than the one that we use because the influence of the structure of the soil, when you consider the cracks due to former presence of ice, gives you a higher permeability.

I hope that that clarifies it a little.

THE COMMISSIONER: You put that very succinctly. I think that sketch should be marked, Mr. Genest.

MR. GENEST: Yes, we'll have it reduced to non-transparent paper, sir.

Mr. Commissioner, we left off yesterday at the concern, I think we had dealt in a general way, which I believe will be illustrated further with impact in valleys, and I was going to turn now to the question of the concerns contained in Sections or chapters 8.1, 8.9 and 8.10 of the Pipeline Assessment Group Report relating to convex ion, icings, drainage and erosion. Dr. Clark --

WITNESS CLARK: Sir, when we left off yesterday we had just finished addressing the concerns in 8.7, river crossings, and 8.8, impact in valleys, and in discussing the river crossings I indicated that we would like to illustrate several of these features by slides which we would do today, and

with your permission, sir, I would like to ask Dr. Hollingshead to initiate the further discussion, and illustrate these with slides on this question of river crossings.

MR. GENEST: Yes, I'm sorry, I overlooked that. Would that be in order, sir?

THE COMMISSIONER: Yes, certainly. Please do.

WITNESS HOLLINGSHEAD: Mr. Commissioner, before I launch into a few slides on our design procedures with respect to river crossings, I thought I might just use one view graph, sir, to perhaps put some of the sketches that Dr. Morgenstern showed you yesterday into perspective, that is with respect to the stabilization berm on the Great Bear River. It seemed to me there might have been a little concern or misunderstanding about the relative size of the structures proposed with respect to the river, and this view graph perhaps helps to put it in a little bit better perspective. This is taken actually from the preliminary design drawings which appear in Section 8.3, which is one of those rather larger volumes, if you wish to look at it in more detail. It's very similar to the berm that Dr. Morgenstern was describing yesterday. I think the important point is that we see here the Great Bear River in plan view. This is the left bank, the higher of the two banks which is the one which was being addressed yesterday. The stabilization berm is shown roughly in its proper size and shape by the red, as you can see it

does not extend a great deal into the channel itself. The channel at that point is about 1,300 feet wide, and the berm probably extends into the channel a couple of hundred feet. Further, the bank does recede there a bit and the berm is feathered so that it fits rather nicely with the side of the channel.

Q You said "feathered", Dr. Hollingshead?

A Well, tapered back towards the edge.

THE COMMISSIONER: Just before you take that away, it takes the rest of us a moment to orient ourselves.

A This is the Great Bear River and I think contrary to what I indicated yesterday when you asked about the distance from Fort Norman, it seems to me it's actually probably closer to eight to ten miles upstream from Fort Norman.

Q The stream is flowing down towards --

A Mackenzie, that's right, sir, north being in this general direction. If you recall, the discussion was about the south bank or the north facing bank. It is the higher of the two banks, it's about 150 feet high at a slope of about 3 to 1. This lower sketch which shows the channel in cross-section, actually is at an exaggerated scale, so this is not a true scale sketch. As I say, the channel is some 13 or 1,400 feet wide at that point. It is very shallow with a depth over this bench on the right side

of something like five feet, a deeper sub-channel of about 10-foot depth towards the left side, and then another shallow channel. The actual shape of the channel is shown by the brown line.

Beneath that you will see the black line which represents the pipeline and it was because of a wish not to cut deeply into the permafrost bank that you will note the pipeline adopts a position which is very close to the ground surface --

THE COMMISSIONER: How deep is the pipeline beneath the bed of the river?

A It is probably about at a 10 foot burial depth here. Now, I might just also--

Q To the top of the pipe or the bottom?

A The top of the pipe I believe is probably about ten foot shown in the preliminary design is about 10 foot below the bottom of the channel there. I might point out that this along with the other major -- so-called major crossings were drilled both in the channel as well as in the bank and in every case of course, the mid-channel borings show that indeed we have unfrozen material in the channels. The borings at this site of which there were two in the channel, indicate that we have in fact a bedrock condition within a couple of feet of the channel bed, so that there is about two or three feet of boulder paving underlain by silt stone and clay shale bedrock. And for that reason one would not anticipate scour at this crossing and in fact it may well be that this design as it is shown is overly conservative.

Nevertheless, that is just another point that was queried yesterday.

Q You gave us the depths of the water on the bed of the north side and on the channel on the south side. What time of year are you speaking of -- July?

A Sir, the low water condition, the depths to which I referred would have been the situation in September, low water August - September conditions. I might also point out that with respect to the Great BearRiver, it is extremely well regulated by Great Bear Lake so that there is not a great fluctuation in flows over the course of the year as there might be in most of the rivers and streams which are tributary to the Mackenzie. In fact, it is an extremely well behaved, well regulated river.

Nevertheless, we show on there a design high water level which is considerably above the September water level. I might also indicate that the dotted red line as shown on the shallow bench on the north side, coming down just below the 40' high bank represents one of these work pads which was referred to earlier, and this is one situation where we preferred not to cut into the slope and hence would propse to build from a work pad which would be a temporary structure, as I said, sticking out into the channel temporarily. This would permit one then to fabricate the pipe and pull it in from that position rather than from a

fabrication area up over the bank as one would normally do. That permits us to bend this pipe rather more sharply than would otherwise be the case.

MR. GENEST:

Q Dr. Hollingshead, excuse me, maybe I have missed something. Could you put the picutre up a bit? The work pad that you show is under water, as I understand that?

A No, sir, this is a design high water level --

Q Oh, I see, you are just showing a sort of a wharf for want of a better word.

A During the period of construction which would be mid-summer, to late summer, the water level would be down here, there would be this temporary structure, then, which would in effect look something like that in plan, would be used to facilitate construction and then would be removed following construction. This was mentioned with respect to the concern for the increased velocities that may be, had been considered a difficult problem from the point of view of the fish.

And now, sir I would like to, during the next few minutes, illustrate for you our river crossing design procedure. As you know, the pipeline does cross several hundred rivers and streams, from the very smallest to the second largest in North America. IN all cases, however, this same design objective holds and that is that we would bury the pipe to avoid exposure, to avoid

exposure of the pipe. What I would like to do now is show you a few slides which explains the approach, explain for you some of the key terms that we use and finally illustrate a typical preliminary design. As I have said, the design objective is, in all of the buried crossings, is to avoid exposure of the pipe. There are perhaps three major considerations, that is to protect the pipe against channel processes of vertical erosion, to protect the pipe against channel processes of horizontal erosion and to provide the pipe with weighting against the bouyant effects of the water.

In order to insure that the pipe is not exposed by vertical erosion within the channel, it must be buried beneath the estimated lowest bed level which may occur during the life of the project. Vertical erosion takes two forms basically. First of all there is general bed degradation which occurs over a long period -- over a long reach of river and usually, although not always, over a fairly long time span, that is a geologic time, not always, but generally, as the river cuts down into its valley.

Clark, Hollingshead, McRoberts
Slusarchuk, Morgenstern, Cooper,
Hardy, Williams
In Chief

So that there is not a great fluctuation in flows over the course of the year, as there might be. Conversely some rivers agrade or build up a bed and in particular one might think of the alluvial fans which are common in the north, and areas such as deltas.

The second form is a much more localized situation and is referred to as scour, scouring, and that -- this action, I might liken to the scooping of holes in a beach as children might commonly participate in, or pot-holes in a road, that sort of configuration.

Rivers do not normally naturally run straight. They naturally meander. Rivers naturally meander and this is a meandering tributary of the Mackenzie crossed by the pipeline. That is to say that they adopt a winding path but not only is it a winding path, but the bends or the meanders tend to move with time. The meander loops tend to move out and downstream by virtue of the lateral migration, erosion on the outside of the bends, and this also then would be the -- the outside of the bends is where one might expect to get a scouring action occurring as well, unless of course the bed happens to be in solid rock. If one, however, just thinks in terms of a stream flowing in its own alluvium, erodeable material, then one would tend to get scouring towards the outside of the bends, as well as some lateral movement.

Perhaps this helps to explain

how or why this occurs. As the flow goes around the bend, in a similar manner to an island, the water surface adopts a very, very slightly super-elevated effect, this induces secondary diving currents at the outside of the bend. So that the top of the slide there we see in plain view the river making its course around this bend, and below that in cross-section the slightly super-elevated effect of the surface and the nature of these secondary diving currents, so that for instance then, material on the outside bank would be -- would tend to be eroded and scour would tend to be greatest towards the outside bank.

The current then carries this material across the bed and deposits it on the inside bank downstream. This slide then again is a schematic cross-section of the channel and I would suggest the easiest way to look at this one is to imagine that you are looking downstream and this will put us all in the same convention as the river engineer, so that we then see on the left-hand side of the slide what is normally termed the left bank; on the right-hand side of the slide, the right bank.

If you can hear me without the speaker, the left bank, the right bank, and we also see on this schematic a designed high-water level which in most instances would most meaningfully be the bank load condition, that is the level which is at or just above the bank, and this tends to be the level which

controls in most instance the shape of

the channel. In a straight reach of this river, the bed level may well look something like the dotted line. That depth of channel is the -- is termed the regime depth and in simpler language, let's just say that that's the mean depth or the average depth in a straight reach. As the river flows around the bend though, we notice that chances are one would get a deeper scouring action resulting in a deeper bed level on towards the outside of the bend, so that one might anticipate a channel cross-section that looked something like that, and this depth then is termed the scour depth. The difference between the two is referred to as the net scour.

Here is our pipeline coming across the channel beneath the predicted scour depth, and it is by virtue of the experience built up, which is referred to as the so-called regime theory which permits us to predict this scour depth. In essence, what is done is a multiplier or a scour factor is applied to the regime depth. This regime depth is either measured by surveying techniques, or calculated and then a multiplier in the range of 1 1/2 to 4 times, depending upon the channel configuration, the severity of the bend, the nature of the bank and so on, is applied to that regime depth, giving us the scour depth. The pipe then is set beneath that predicted lowest bed level. Next, please.

I might just say that I think Dr. Cooper will also probably have a few words

to say about that and elaborate a little further on where and how much scour one might anticipate.

This slide shows how a meandering stream continues to, in some instances, particularly in a stream which has fine-grained material on the banks, continues possibly to contort the bend, a lateral migration moves the bends out and becomes more contorted configuration until the possibility of a natural cut-off exists. This again is a planned view of a schematic of a stream with very contorted meander bends. I put this up here to illustrate that this is one instance or one natural situation in which one might anticipate some general bed degradation over a reach of river. As you can see, before the cut-off, looking at the profile, it appears the slope of the water, the bed level with local scouring at the bends, this distance from point 345, having gone around this original path, has been shortened to 35, by virtue of the cut-off, resulting in a greater slope to the channel, and to get itself back into regime or back into equilibrium, one will anticipate some general bed degradation in that reach. Thus if for instance you had a proposed crossing near point 6, you would want to be able to predict that eventuality to allow for this extra bit of bed degradation which may be superimposed upon your local scouring in order to establish a safe burial depth at point 6. Next, please.

Unfortunately this is a rather

dark slide, poor slide, but this is a picture of Big Smith Creek which again is a tributary of the Mackenzie and which the pipeline crosses, but it shows these very contorted meander loops, and the potential for a natural cut-off. Next, please.

This is a better shot of the same sort of possibility, this time the Martin River which is south-west of Fort Simpson, again a potential cut-off of that meander loop. This then of course ultimately would be cut off and become one of these so-called oxbow lakes. Next, please.

Now not all streams develop that same very contorted meander pattern. The other type of lateral migration or lateral movement results in a down-valley shifting of the meander pattern so that here we see at the top of this slide in plan view, a meandering stream, flood plain on either side, the valley walls, out here. The present course of the channel is shown by the pair of solid lines, a former course by the pair of dotted lines, and you can see that the meander pattern is shifting in a downstream direction. This is a result of the erosion of material from the outside of the bend here, and carrying of that material across the bed and deposition on the other bank, so that this is new material recently deposited in the cross-hatched area, eroded bank. Next.

The lateral migration of the channel is part of the regime analysis that we go through and this is assisted in very great measure by having aerial photography flown in different years at different times, so that we have -- when we have time sequence photography, it is extremely useful in helping us to predict, if you like, or observe how much the banks have moved over the past number of years, and therefore predict how much movement is anticipated over the next several decades. Here we see an application of that, I'm not sure how clear it would be from the other side of the room. What you can see here, the former channel of the Salcha River near Fairbanks, that was its position in July of 1950, and its position in August of 1969 as a result of the lateral migration, the moving out of the bend, moving out of the bend here, a shift something in the order of a channel width of about 200-250 feet. Here nearly two channel widths suggests that point has moved out probably 500 feet, in that 19-year period. Next, please.

I suggest that there are probably two key points in the design of the crossings, one is to get the pipe below the predicted lowest bed level; the second key point is to ensure that we have this sag bend sufficiently protected, that is sufficiently deep into the bank that it will not be exposed by this lateral migration of the stream. Those are probably the two key points in the design. This shows us then, looking again -- imagine you're

looking downstream at the right bank of a hypothetical stream, high water level, the right bank, the pipeline coming from beneath the channel through a sag bend, this is being termed a sag bend up the bank, through an over-bend and then on its merry way across the country at a prescribed depth.

I've already established the top of pipe here by our scour predictions, and we would establish, to find this point at the end of the horizontal section at the sag point and that is established by studying the lateral migration of the channel, using aerial photography, knowing what the bank material is, the vegetation, its thermal condition, etc., establishing that point so that there is adequate lateral protection for the pipe as it comes up from beneath the channel. Next, please.

This illustrates that technique with respect to the Sag River near Prudhoe Bay. In plan view again, this is looking at the left bank configuration of the Sag River, the river is flowing northward. This is the proposed crossing on the coastal route and this shows you in the hatched dotted line the position of the left bank at that crossing in 1955. The solid line shows you the position of that left bank in 1971, and as you can see, there has been some down-valley shift of that bank at this point, as well as erosion in the lateral sense. One might then predict that that bend is going to, with time, move further down-valley, and

possibly impinge on the crossing. In addition to that there may be further erosion towards the left, possibly something in the order of 100 feet in that direction, so that one wants to then have a good handle on that before you establish your sag point, the point where the pipe will come up beneath the bank.

Next, please.

This leaves us with a number of different alternatives for the design. One alternative, having looked at that and studied the situation, might be to say bury the sag point at a depth a distance of some 400 feet into the bank. This would presumably then take care of any eventuality over the life of the project.

Alternatively, if that proves to be an uneconomic or an expensive procedure, expensive deep burial, one might alternatively propose to put that sag point at a depth of 250 feet into the bank and provide for monitoring procedures and develop prepared plans for river training works or some other bank armouring procedure. In other words, reduce the depth of deep burial which is required, monitor the bank and have contingency plans prepared to maintain the channel in its present configuration. Next, please.

This is a view of the Willow Lake River at the crossing which was proposed prior to the recent revision east of Fort Simpson. I put this up here to give you -- to help us get through the next slide which may prove to be a little bit more difficult than others, but the proposed crossing we're

going to see on the next slide, is about at this point, not too far removed from the highway location, and you're familiar with that bend in the river. It's a very short distance upstream from the mouth of the Willow Lake River. North is off to the left of the stream. Next, please.

This is a piece of the Willow Lake River that you were looking at, the view in that last slide, just looking down on the crossing about here in that general direction. In the upper right of this slide here,we see a cross-section of the right bank of the Willow Lake, that is this bank, the proposed pipeline coming up from beneath the channel into the bank and the design water level. Now if you can imagine yourself standing in mid-channel and looking along the pipeline toward the north, that is you're standing here, looking in towards the right bank, you would see that, because this is about a 25-foot bank, that you would, looking at a section through that bank, just about at the sag point, at about this point here, you would see roughly 20 feet of silty clay overlying a sandy material. There would be a cut excavated into that bank and then a ditch in the order of 20-foot deep excavated from the bottom of the cut, and here we see at the bottom of that ditch, a 4-foot diameter pipe. This ditch and part of the cut is backfilled with native material, and then that native material blanketed by a two or three-foot blanket of select backfill material to protect the surface against subsequent --

against any possibility of failure or erosion and sedimentation of the stream. Built into that surface may well be two or three weirs, low mounds across the swale, again of select random material which would control the down-slope movement of the surface water. Next, please.

THE COMMISSIONER: What are the depths of the various fill materials?

A This is on this sketch in the order of 20 feet, and we're looking at about probably another 15 feet here, so that I suppose about 7' here, sir, and a similar depth above that. This is a little out of scale. I would anticipate that that blanket would probably be in the order of two to three feet.

Q At what depth is the pipeline buried at the crossing beneath the river bed?

A Beneath the bed it's in the order of about ten feet of cover here, and it's about 30 feet of cover here.

Q 30 feet of cover at the sag bend.

A Yes, something of that order.

The third consideration which I referred to in the introduction was the necessity to weight the pipe against the buoyant effects of water. Here we see three possible types of gravity restraining measures. The top sketch shows you a piece

of pipe which is -- has been coated with a continuous concrete coating, for our project this would be in the order of five to six inch concrete coating. It is a continuous jacket which would be used in the major crossings where we propose to pull the pipe into position in the ditch. It would be reinforced with a wire mesh, and it would probably be articulated or cut, if you like, at certain specified distances to permit the bending.

Alternatively, in the smaller streams, smaller crossings, the pipe would be weighted by individual bolt-on weights. That is in situations where it is not proposed to pull the pipe into position, but rather where you have, for instance during the winter construction period, no flow, you're working off the ice and you would simply walk the pipe in and place it in a ditch. You would probably see these bolt-on types used.

The third type that is illustrated is referred to as a set-on weight or saddle weight, and it would not be used in any river crossing application. This would be restricted to use in other buoyancy areas, swampy areas and the like.

Next, please.

This illustrates the first two types of weight that I described, the two-inch continuous concrete coating and four individual bolt-on weights at the lead end of a 12-inch gas pipeline, a crossing of the Columbia River just downstream from Trail, B.C.

Next please. This final slide then illustrates for you a number of the things that we have talked about. This is a preliminary design of the Peel River. Here we see in cross-section the Peel River Channel for which the design flow is some 300,000 cubic feet per second. The low water level in September at the time of the survey illustrated here, the design high water level at this particular level, We see on there the solid white line is the pipe. It illustrates the location of the sag point . This sketch, although you probably cannot see the detail of it, also illustrates the testhole data which available at that site with silty clay in the banks, clay overlying bedrock at this elevation. Within the channel itself silty sand, gravel and silty sand overlying glacial bedrock at that elevation.

We see the sizing and so on of the pipe and also the extent over which the pipe is weighted.

THE COMMISSIONER: What is the width of the crossing of the Peel?

A At that crossing I believe it is some 3,000 feet, probably less than that. Just a little over 2,000 -- about 2,400 feet.

MR. GENEST: Measured from where to where, Dr. Hollingshead?

A Well, from this point --

Q] From the overbends?

A Roughly between over

bends, about 2,400 to 2,500 feet.

Thank you very much.

THE COMMISSIONER: Thank you, Dr. Hollingshead.

WITNESS:CLARK:

A Sir, with your permission, we would like to ask Dr. Cooper to add some comments and illustrations to this.

THE COMMISSIONER:

Q Could I just ask Dr. Morgenstern one question while you are getting ready Dr. Cooper. You said that there were approximately 200 river crossings in Canada, river and stream crossings, I think you said that.

WITNESS HOLLINGSHEAD:

A Well, I am not sure I said that or not, but that figure has been used. I --

Q Well, if you are not sure whether you said it then I am not sure where I heard it.

A No -- I agree that that figure has been used. There are I believe, for instance in the E.P.B. Report, they flag 650 crossings or watersheds, that is within the two territories. these 650 of course encompass everything from the Mackenzie down to the very smallest creek and that is probably not a bad figure. Of those 650 quite a few would not be given individual consideration. I would guess that of the 650 there are probably

150 to 200 which will indeed be given individual consideration, if you like and these will be selected, these significant crossings, the majors and other minors which are considered significant crossings, will be selected, if you like, as part of the ongoing studies, in fact, within the very near future, in the next couple of months.

WITNESS CLARK:

A I think perhaps to add a note, sir, that the 200 or so rivers or ones for which there will be a specific design, the very small creeks are treated in a typical design that would be applied again and again for a very small crossing, having similar characteristics.

THE COMMISSIONER:

Q You do not dispute the estimate by the Environment Protection Board that there are something like 650 river and stream crossings.

WITNESS HOLLINGSHEAD:

A I would not dispute that at all.

Q Just one last thing. You said that one of the crossings, the major crossings, was the second largest in North America?

A No, I believe what I meant to say is that the Mackenzie is the second largest river system in North America. I would not be surprised if some of these crossings are amongst the largest.

WITNESS HARDY:

A Well, there is no question about that, sir. The crossings of the Mackenzie are certainly the second largest on this continent in length and in difficulty with the ice conditions, they do represent very severe crossing conditions.

THE COMMISSIONER: Well, thank you, Dr. Hollingshead. Again, Dr. Cooper?

WITNESS COOPER:

A Mr. Commissioner, Dr. Hollingshead has given you an outline of the elements of a river crossing as it would be constructed. These include deep burial, a sectional deep burial that would accomodate vertical erosion processes. They also include the location of the sag bends. This is to of course accomodate the lateral processes of the river.

What I would like to do in my presentation is to go into somewhat more detail as to the considerations that go into the analysis of these processes in determining the actual. I shall deal with scour, local scour due to open water conditions and then local scour that would result from the formation and the development of a severe ice jam on the Mackenzie River. I shall deal with the process of channel degradation which Dr. Hollingshead got into in some extent and I shall finally discuss briefly the processes, the lateral processes that of course have to be considered in setting the sag bends. Can we just have the --

The first set of slides deal with scour due to open water processes. Now, as Dr. Hollingshead mentioned, local scour is due to the erosive velocities of the flow and it develops to a significant extent where we get a diving component of the current, such as on the outside of the bend. The things that we consider, the types of data that we consider when we analyse the process are the entire spectrum of flows that can occur in the channel, the general alignment of the channel, whether it is on a gentle bend, whether we are dealing with a straight reach, whether it is impinging for example on a high bank, we consider the vegetation on the floodplains, what that does to the flow, and we also consider the bed materials, whether we are dealing with a gravel paved bed or whether we are dealing with a fine sand.

The first slide illustrates local scour that might occur at an unconfined meander bend, that is, a meander bend that is allowed to freely erode. What we have here is the meandering channel, bounded on either side by relatively low floodplains. You will notice in the first section, drawn through location "A" here, that we do have relatively low banks on either side. When we get a flood, these banks are over topped and they can be overtopped by some considerable heighth. What happens when we get a flow going through this staight region, approaching the bend, is it impinges upon this bend and that is how we get that diving

component that can erode the bed materials and create a scour hole. Generally a scour hole would appear in this location.

Now, for this type of situation, we are of the opinion that the scour would be maximized generally at flows approaching or slightly exceeding the bank full condition, because when we get higher flows than that, we tend to get a general straightening of the flow, in a down valley direction and these actually tend to depress, if you like, the tendency for the diving current. We would also get a deepening of the bed, possibly even on the inside, on the point bar side of the bend, so for the case of this low floodplain, the bankfull conditions we feel to be the most critical for scour.

Now, when we compute scour, we compute it as a multiple of the average depth of flow in the approach section. approach section to the Now, you notice the second section taken at "B", right through the potential scour hole, indicates this diving component of the current and it indicates the development of scour. In this particular type of bend, we would expect scour holes to be developed in the order of 1.5 to 2.5 times this average depth at bank conditions. The choice of the value within this range would depend primarily on a radius of curvature of this bend.

Can I have the next slide please. This is a photomosaic of a similar drawing

that Dr. Hollingshead illustrated. It is the Salcha River which is being crossed by the Trans-Alaska Pipeline in Alaska near Fairbanks.

Now, this is an illustration of the type of river that would be treated in this manner.

You will notice that these are relatively, although we don't have a section, they're relatively low flood plains, they are quite heavily vegetated but as Dr. Hollingshead pointed out, the erosion rate along the outside of the bend, in here and in here, is quite rapid. This is quite frequently flooded. There are significant point deposits. If we were computing scour at this location, we would take the average depth at bankful conditions, at some straight approach section and apply or multiply, I would say in that instance in the order of 1.8 or 1.9 to come up with a scour depth. Now, I indicated what might happen when we get higher flows. We would get the entire flood plain area being inundated and we would get a general straightening of the flow, more on a path like that. There would still be curvature but it wouldn't be as sharp as we had before. The flow in this direction, much of it would then pass over the flood plain. The part that went over wouldn't add significantly to that diving component. Next slide, please?

The next situation of local scour refers to that of a confined bend, that is one that is not allowed to freely erode. The illustration at the top indicates an approach channel that is actually impinging on a high terrace wall. You can see that section through B in the lower section here. Now this is impinging at a relatively sharp angle and we get an abrupt turn in the direction of the flow. I think we can all see that under conditions like that

that sharp angle of attack and the abrupt change in flow direction would actually increase the tendency for that curve to dive, if you like, and dive and create that corkscrew type flow , and this would tend to increase the potential for scour along the outside of the bend. Again, when we compute scour, we reference it, in this case to bankfull conditions. We compute scour in terms of the average bankfull condition for a straight approach channel upstream of the actual location we're dealing with.

Now there is an error in the drafting here. The range of values that we predict or that could occur in the case of a situation like this, range from 1.5 to as high as four times the average depth in the approach section. When we get flows higher than bank full in this case they will -- the entire flow will impinge on this wall and this will tend to increase again this diving component, so that has to be accounted for in scour. We don't have that relief of it flooding all over the flood plain that we had in the previous instance.

While we know that it is the large flood in this case, or the extreme flood event that actually may produce the maximum scour, we still reference the scour depth to the bank's/ full depth. Now the reason we do this, is that the range in Z values and our experience in using them is based on a consideration of a variety of field observations of scour holes and of laboratory tests on scour holes. So that the important thing is to, at all times, reference

your computation to scour to one specific stage, if you like, in this case bank full even though we may know that it was actually a higher stage that was responsible for the development of that flow; but to bring all the data onto a consistent base, we would make that computation on the basis,both in developing the curves that we're getting these numbers from, and in actually doing design,we would bring them all to the common base of the bank full condition. May I have the next slide, please

This example is taken out of one of Dr. Mollard's textbooks. It's Beaver River in Saskatchewan. We have a case here where the valley walls if you like, valley flat extends for approximately here to here. This valley is too narrow to allow the river to develop the meander breadth that it would like to. Hence the river is constrained by the valley. It would like to develop a meander breadth that goes . way out in here. What it attemptsto do that is cut off here and it's forced to go downstream and it starts another normal meander loop cut-off again and so on. The direction of flow is like this. As you can see, we get a rather sharp impingement on this valley wall, a rather abrupt turn. As flows come down here, we get that diving component and hen ce the rather high scour valley . Next slide, please.

Here is an example on the Bell River on the Canadian portion of the interior route where we have both of the processes I've just discussed illustrated. Here the proposed crossing

of it, we've got relatively low flood plain areas on either side. If we could get overtopping of these banks then we wouldn't have a severe diving current at that location. I believe, however, you can even detect on the differences in tone on this photograph a darker blue in this area, indicating that it is deeper. Had the crossing been located further downstream, we would get this flow impinging on this higher bank, and we would get a stronger diving component. We would have to bury the pipe deeper in that instance.

Next slide, please.

The next illustration deals with local bed scour as it occurs at a confluence of two channels. For purposes of illustration, I've selected or I sketched a braided river. Now here we have the active channel area of that braided river, there would quite likely be a number of sub-channels throughout this. Here I've illustrated a location where we would expect scour associated with a freely eroding bend. Here we have an illustration of scour that would be associated with a somewhat confined bend; and here we have a location where we would expect scour that resulted from these two sub-channels coming together in a confluence.

Now if I can refer you to the first section, drawing 2-A, generally these, in this particular instance, it would be relatively broad, relatively shallow. Again we're going to reference and compute our depth of scour on the basis of the average

depth of this approach channel. Now when these two sub-channels come together, the flows come together, they create a diving current as if there was a wall between them, right in the centre of the channel, so if we draw a section downstream of the confluence at B, through the scour hole, we have this situation. We have this diving current in the centre and we now get instead of on the outside of the bend, we get a scour hole developing in the centre of the channel.

The depth of scour, again reference to the banks full condition, in this case, can be expected to range from two to three times the depth of flow in the approach channel. In some model studies that we carried out for Aleyeska, we obtained quite a bit of data on depth of scour in confluences. This data surprised us to some extent in that we were getting depth of scour in this instance that were quite a bit higher than we would have thought would occur prior to doing these tests. Next slide, please.

This is a photograph of the east Chandler River in Alaska on the interior route. You can notice the very numerous sub-channels in this case and we can see several cases where we can get a confluence dev eloping. Now we would design literally all braided channels for the event of scour attributable to a confluence, because braided channels are the type that we can get very rapid shifting, rapid changing in the location of the sub-channels. The confluence situation is the most severe of the three that I've discussed, although I did mention that we could get a

multiplier to scour of four in the case of the abrupt impingement. However, where we get this freely eroding situation, or freely migrating situation, in the braided channel we cannot get the severity of impingement on the river banks that would produce that high a value, so the confluence is the one that governs in the braided river. Next slide, please.

O.K., I'll now switch to a brief discussion of ice jams and scour attributable to ice jams. The studies that have been undertaken on this project with regard to ice jams in the Mackenzie River have involved both field studies over the last several years and office studies, where the phenomena of ice jam development and associated scour has been analyzed. I would like to point out that the preliminary designs that are shown in the application and in the supporting documents, have been based on open water scour conditions. However, many of these reports indicate that scour due to ice jams is definitely a major design consideration, and would have to be taken into account prior to final design. As the result of the studies that have been undertaken, we now have a conservative prediction of the maximum scour that can occur due to a very severe ice jam in the Mackenzie. I'll quote some of the numbers, scour numbers later on.

Now here we have a plan view of a wide single channel river. We get ice flows moving downstream with the flow of the water. What we

need to initiate a jam is for several of these flows, possibly several of the larger ones, to interlock and to key themselves into the banks of the river.

Once that happens and I have illustrated three such ice flows doing that, we essentially get an arching situation here and these flows are now a barrier on the surface and they block off flows as they approach it. Looking at it in logitudinal section, we have got this jam initiated. We have got it keyed at the downstream end. As the ice flows then approach they would be thrust under the jam and the jam could thicken. Now the forces -- it is the hydraulic forces of the flow that thrust them under -- the velocity on the surface at the upstream end of the jam. As the jam thickens we get a constricted waterway beneath the jam. With this constricted water way we are still passing approximately the same discharge as prior to the jam, we get higher velocity and we get a zone underneath the jam where potentially scour can occur.

Next slide please. This sequence of longitudinal profile is intended to illustrate the development and growth of an ice jam. Stage one is the formation of the ice jam which I described in the previous slide. WE would get a keying of the jam at the upstream end. We would get ice flows approaching it. As they got to the upstream end of the jam, they would be thrust underneath. Phase two covers the thickening process of the jam.

Now, as these ice flows are thrust underneath the jam, it would tend to thicken. As it tends to thicken, as I described on

the previous slide, we get constricted flow area beneath the jam and we get scour of the bed.

Scour initially occurs at the upstream end of the jam. Now, as a result of this scouring process, the transport downstream of that scour hole becomes greater, the capacity of the flow to scour becomes less at that point in time and we get just a gradual development of scour here. Now, this would be at some increment of time after the jam reached this thickness. The material of this scour would be deposited in the area downstream of the jam. This deposited material then results in higher water levels for the same flow downstream of the jam. At the same time, the increased resistance due to the jam and its constriction, results in an increase in water level across the jam and the two causes of water level increase result in significantly higher water levels behind the jam. These higher water levels increase the flow area and at some point where -- at some point of velocity and depth, we get a situation where the approaching ice flows can no longer be thrust under the ice jam. At this stage the ice jam continues its growth by growth upstream. It no longer thickens.

Here, we have the approaching ice flows, stack themselves up and we get a contour -- shall I call it -- the rear of the ice jam is then advancing upstream. Again, we get the same sort of scour underneath the upstream end of the jam, but since this front is now advancing upstream, it -- the

scour cannot proceed to equilibrium. At this point in time we get an actual infilling of the initially deep scour hole. We would also get somewhat more scour down here and again, additional deposition.

Generally speaking, our analytical studies tell us that once this condition occurs, the most severe scour stage has passed. IN fact, the most severe bed scour occurs during the first few hours or the first day after the jammed formed when we get a depth of scour here that is approximately equal to the submerged thickness of the ice jam.

Now, I would like to just discuss for a moment, although some of these points are not illustrated on this slide -- the forces acting on this ice jam. To begin with we have got a sheer force due to the interaction of the flow which is moving under the ice jam and the stationery, usually very rough bottom surface of the ice jam. This creates a sheering force which tends to move the ice jam down stream. We also have a net hydraulic pressure force, we have got some acting on the upstream end, some acting on the downstream end with a net force in the downstream direction.

Lastly, we have a downstream component that, in the slope of the river due to the weight of the jam itself. Literally it is just a huge mass that is attempting to slide downhill. That is a force tending to move the jam downstream. All

of those three forces tend to want to break the jam up. At the same time, the jam is restrained. It is restrained by the sheer forces acting between the ice and the banks of the river on either side. These sheer forces or these total forces are a function of the thickness of the jam, whereas the major force that is attempting to move the jam downstream is a function of velocity and the breadth of the river, the total breadth of the river.

Now, for a wide river like the Mackenzie, there is a limiting thickness beyond which the sheer forces become so great that they will break the jam up and the equilibrium or the maximum scour that could normally develop due to thickness before we would get this release from the upstream growth, usually does not occur for the most severe conditions. Normally we would get the break up occuring first. Now, for less severe conditions, which would result in less scour due to this cause, we can in some instances get the upstream growth and this we have observed in the field.

The result of our analytical studies has indicated that we can get a net scour during this process that approaches 30 feet. By net scour I mean the amount of scour from the existing bed at the time of formation of the jam to what it would literally dig itself down to.

We have talked to our construction people and have got every indication that construction of the pipeline beneath that level with

an adequate margin of safety, is completely feasible.

Next slide please --

THE COMMISSIONER:

Q Dr. Cooper, when you say you may get a depth of scour to 30 feet beneath the bed of the river, were you speaking of the Mackenzie or of any number of rivers?

A Mr. Commissioner, I was speaking of the -- and I did not properly state that case. We have concentrated our analytical work on the worst case of an ice jam that we could envision and that is on the Mackenzie River in the vicinity of the point of separation reach. There we have the strongest ice at the time of break up. There we have the probably highest flow velocities and we have a sand bed, which is critical to the development of deep scour due to this process. So I am talking about that most severe case, the point of separation for the 30 feet.

In actuality the Mackenzie River, we feel is the only river with severe ice jamming problems.--Icejamming related scour problems of this nature. We have investigated the Liard River and the Peel River, but for various reasons, the hazard is just not the same on either of those rivers. Okay?

The next sequence of slides, the first three will illustrate a jam on the Mackenzie River and although the next three have not that much to do with my talk on scour, I thought

they would be of interest. They illustrate ice push up at the Rampatts that we observed in 1974.

This jam is viewed from the leftbank of the Mackenzie River, some 10,000 feet upstream of the presently proposed Point Separation crossing. You will notice the downstream end of the jam, the flow is from right to left. The open water area here. We get this jumbled mass of ice flows on the surface upstream of this and can I have the next slide.

This is a view of the jam taken looking downstream a further 8,000 feet -- I think this is going to come out confusing. The location here is 8,000 feet further upstream from the previous photograph, or 18,000 feet upstream of the proposed crossing. WE are viewing it, looking downstream from the left bank, from a rather narrow floodplain area there. You will note first of all the oil drum on the ice jam, but you will note that the height of the jam here is well up into the floodplain area. WE have got a good, I believe 30 feet of rise in stage over the open water condition downstream at this point. You will notice the size of the ice flows and the orientation of them, some of them even approaching the vertical in here.

Next slide, please. This is a view of the ice jam at essentially the same location except that we are looking across the river from the left bank. Here at that low flood-plain or terracearea. The last photograph was taken

from approximately here looking downstream. Again, this illustrates the jumbled mass of ice in the jam and the relative level of it compared to this area.

Next slide please. This is a photograph taken during the 1974 break up on the Mackenzie River and it is taken at the Ramparts. Now the Ramparts, for those of you who are not familiar with the Mackenzie, it is a narrow passage of the river that is bounded on either side by very steep bedrock walls. This location here is some 80 feet above the channel level or the ice surface or water level down here. The ice -- the flow is approaching in this direction and the ice has started to come in here and started to be pushed up the steep bedrock walls.

Clark, Hollingshead, McRoberts
Slusarchuk, Morgenstern, Cooper,
Hardy, Williams
In Chief

This slide will illustrate how high that got pushed up. This is the same location and you will notice the ice has been pushed up to above that 80-foot level, which of course is above the water level or the ice level of the normal river. Next slide, please.

This is what it looks like after the first push-up. You can visualize this ice is coming into this very constricted section of the river, these big flows are being shoved up and thet then fall back in, and we get what appears to be several ranges of mountains, if you like, of this jumbled, broken ice, that prevents further push-up. In other words, the push-up of ice now turns down here as an ice against ice process rather than an ice against the river bank process. Next slide.

The next two slides refer to the process of channel degradation. This one is very similar to the one that Dr. Hollingshead illustrated. We have here the potential cut-off and let's say that we have a pipeline crossing just upstream of that. Now as this cut-off occurs, cut-off of a meander loop occurs, we get a reach of high local slope . We get high velocities and bed erosion, on that reach of high local slope. These velocities will tend to start cutting the slope back. The pipeline, for example, would be back here. The cutting back of that slope and the resulting bed configuration is shown in the bottom profile. Ultimately this slope would be cut

back with some flattening until we would get possibly several feet of degradation over top of the pipeline. But we would get at the same time some deposition in the areas downstream. This is just to illustrate that in selecting burial depths we have to look very carefully at the processes of channel straightening essentially that can occur downstream of a crossing. Next slide, please.

Here are a number of other situations that would similarly result in degradation at a pipeline crossing. The first case is that simply of a set of rapids immediately downstream from the crossing. We have to ask ourselves, "Are these rapids stable over the range of flows that can occur?" If they are not, "Are they liable to tend to migrate upstream and pass over the crossing?" If the answer to that question is "Yes," then we would probably have to bury the crossing a further distance down that would be approximately equal to the drop over those rapids.

The second example illustrates the effect of borrow areas which, of course, are very important to the pipeline. The one I've shown here I've illustrated a borrow area downstream from the crossing. Now there is no real problem with this from the point of view of degradation, as long as the borrow area is designed such that the depth of cut is not deep, because for degradation to occur we have to create a reach of high local slope in here that in turn would migrate upstream. On the other hand, what if we have a borrow area up here? That also has to be

considered because what happens is the flow that's carrying bed sediment and approaching that borrow area would then start to deposit its sediment in the borrow area. The flow that's passing out of it would then be relatively sediment-free. It would then have the strength, if you like, to pick up sediment and result in some bed degradation downstream. Now generally the same principles hold. If we don't take too much and if we don't cut it too deep, and if we put it on the right side of the channel, or the correct side of the channel, say on the inside of a bend, we're not going to get into serious problems; and the other thing is that we have to be careful that we don't build our pipeline downstream on continuous, that's year after year after year, gravel mining operations, because then we're getting that continuous taking out of gravel and a complete starving of the sediment load downstream.

The third illustration is again refers to the sort of thing that happens when we remove the sediment load from a river. In this case when we build a dam, the sediment load -- the bed that moves along the bed would fall out in a delta somewhere upstream. The suspended sediment would for the most part fall out in the reservoir. We have now got essentially clear water passing through over the dam. This water now has the capacity to erode. It would result in degradation until the -- if we're in relatively coarse gravels, with cobbles and boulders,

until the bed paved itself. Next slide, please.

This slide is intended to illustrate the various things that we would consider when we're setting the location of sag bends, and when we're attempting to predict the lateral migration or the lateral processes that might occur. To illustrate these concepts I've sketched a meandering single channel flowing through its own flood plain which is bounded on either side by a relatively high terrace and further out, by the valley walls. This is the terraced area, the flood plain, the channel, and so on. I've illustrated here two potential crossing locations. Now there are essentially three things that we have to consider when we are concerned or when we're analyzing potential for lateral migration. The first is how fast is that meander pattern or the channel pattern migrating downstream? For example, the river is right here today. Could it ten years from now be like that? If the answer to that question is "yes", then in crossing that system we would have to put the sag bends such that in the deep burial mode we would span the entire pipeline era. In most cases or in many cases the answer to that question is "no". We then have to concern ourselves with what the channel does in 20-50 years, how much can we expect it to erode and migrate? Once determining that, we have the third question: Can this channel location be completely abandoned in a single event, and things like a cut-off occur? For example, during a large flow or a large flood, could we get a cut-off

from here to some point downstream? If the answer to that one is "yes", then we would have to again span the entire meander belt.

The types of data that we examine to answer those questions are aerial photographs, and the sequential aerial photographs that are available. Throughout all of the Canadian route and most of the Alaska route there are approximately 20 to 25 years of aerial photographs available. This gives us a history of what has happened over this span of time. It does not tell us the rates at which these things happen.

For example, I could have in 20 years, indicate 50 feet of migration of that channel. Now those two photographs don't tell me whether that occurred in -- as a result of two floods or whether that occurred at a rate of three or four feet per year. All we do is we get a feel for what has happened in that span of time.

Other things that we look at are flood plain vegetation, the bank materials, the thermal situation, thermo-equilibrium within the banks, the flow spectrum that we can expect the river to carry, the severity of attack on the outside of a bend, for example if this is very sharp in here we would expect more rapid lateral migration.

The two sections that I've drawn here illustrate several possibilities, depending on what the answers to those previous questions that I posed would be. Let's first consider the section I've drawn through "A" in the valley. Now if the

answer to the question, can that entire meander pattern shift downstream rapidly in terms of the engineering length of this project, and the answer to that is "yes" then we would have to cross in essentially the configuration that I've shown in 1.

If we can answer "no" to that then we're looking at O.K., how much is that going to migrate during the course of the pipeline, and in all probability we would have to take the pipeline or place the sag bend outside of the terrace area because in all probability we would get migration through this low flood plain. The actual height of the bank here will tend to slow down the migration. At the same time there we're in a deposition zone. We could bring the sag bend up fairly close to the existing bank of the river.

Let me go on to Section B. Here we have what essentially is a confined bend. We would get higher scour here and we would normally think that is a problem, but it may be a very good place to cross the river. Again if we feel the entire pattern goes through here, we would have to cross in deep burial mode across the entire flood plain width. But if this is stable and in many cases it would be very stable because it would be cut into that high terrace, we could come right up in this terrace, and at the same time we know this is not going to shift very much so we could come up relatively close to the existing bank. So even though

we would be facing deeper scour at this location, we would have the shortest crossing of the alternatives that I've mentioned. Next slide, please.

This is a photograph of the Trail River. This is on the coastal route in Canada, and I've just shown it to illustrate some of the considerations in sag bend location. Here we have what we refer to as the active channel area or I believe in Dr. Mollard's terrain typing he refers to it as the active flood plain area.

THE COMMISSIONER: What was the name of that river?

A Trail River. I'm not sure whether it's in Yukon or the Territories, it could be Yukon.

This area would be a flood plain area. It quite likely would be inundated or covered with water at the higher discharges, as would this area here.

can
And this area here, the vegetation you/see is somewhat more dense here than back further. We have a higher terrace along here that is quite likely a fossil floodplain and would not be inundated by even the highest flows. WE have to keep --

THE COMMISSIONER:

Q What do you mean by fossil floodplain?

A At some point in geologic history, this was probably an active floodplain. Now, either through river degradation, longterm geologic river degradation over a span of thousands of years or through the rebound since glaciation of the entire country, or landscape if you like, and
through
the river essentially cutting / its same path as before, we get these old floodplains abandoned and they now exist at a higher level.

In crossing anywhere on this river we would take the pipe -- we would consider this very unstable -- it could erode out rapidly --
in
we could get a channel developing here, and we would definitely cross this in a deep buried mode to accomodate the vertical river processes of scour and degradation. WE would probably consider bringing the pipe up, once we got out into this terrace area, so -- and in all cases on these braided rivers, we are going to be deep buried throughout the active channel area.

Just to summarize, Mr. Commissioner, the river engineering design that

will be done in final design are I believe based on well established engineering principles. Admittedly, these designs, the carrying out of these designs requires a high level of engineering judgment. This science, if you like, has evolved over the past several decades, where we have had a number of rules of thumb and guidelines to work with and judgment has always been a significant factor in the work.

Recently, there have been serious attempts to quantify things like scour. Much of this work is well documented in the various documents that are available on this project and have been filed. In many cases there is data that is required to complete the final design. However, I would like to emphasize that all of this design data is required not to precisely select the location of the crossing, but rather it is required to determine exactly the burial depth that is required and to determine the exact location of the sag bends. In a few instances, such as the case where we have ice jam scour, it is desirable to carry out additional studies and to acquire additional data. In this case, however, it is for the purpose of further refining our design because we feel that the numbers we have now come up with are overly conservative. They are based necessarily on some very conservative assumptions.

I am sorry -- I would like to read out the reports that contain much of the

informaiton that I have talked about and the information upon which I rely. There are several so I shall read them. "The Design of Pipeline Crossings at Braided Rivers", prepared by T. Blench and Associates in January 1975; the reference book on Water Crossings, volume II, "River Crossing Design", prepared by Northern Engineering Services, October 1974; "1974 River Break up and Ice Study --Mackenzie Liard and Peel Rivers, Data Report", prepared by T. Blench and Associates in July 1974,; "The 1974 River Break up and Ice Study -- Mackenzie, Liard and Peel Rivers, Engineering Report", July 1974; "Breakup Observations on Northern Rivers 1973" prepared by T. Blench and Associates in June of 1973; "Criteria for River Engineering Aspects of the Design, Construction and Maintenance of Buried Pipeline Crossings" prepared by T. Blench and Associates in March of 1973; "River Engineering Aspects of the Design of Proposed Pipeline Crossings of the Mackenzie, Liard, Great Bear and Peel Rivers", March 1973, again by T. Blench and Associates; and also I would like to list the information contained in the requests for supplementary information which I believe has been filed as exhibit 70, is it?

MR. GENEST: Sir, would this be a convenient time for our break?

THE COMMISSIONER: Yes, thank you, Dr. Cooper, thank you very much. We will take a break for coffee.

(PROCEEDINGS ADJOURNED)

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

MR. GENEST: Mr. Commissioner, I believe Dr. Cooper, had one additional comment he wanted to make in relation to his slide presentation.

WITNESS COOPER: Yes, Mr. Commissioner. I'd just like to point out that in my presentation I indicated, I believe, quite definitively that the scour holes that we can expect in a river in all cases would form in a very predictable location. For example, on the outside of a bend.

Now this in fact is not always true. It is true that the deepest scour holes form at that location, but as a low flow phenomenon say your annual floods or even lower flows than that, we can get the deepest portion of the river, the deepest thread of the river, if you like, which we refer to as the thalweg --

THE COMMISSIONER: As the what?

A Thalweg.

Q Would you like to spell that?

A T-H-A-L-W-E-G.

MR. GENEST: It sounds like a King of Norway.

A We can get that deepest portion forming at other locations, which may not coincide with, for example, the outside of a meander bend. However, the holes that so form would not be as deep as the ones that I have referred to that we

would use for design. The reason I'm adding this point to my presentation is that this has been a cause for exposure or for loss of cover in any event, in some considerable number of river crossings that have been installed without the benefit of river engineering. It is not, I do believe, a concern for the designs on this project because we would be predicting scours and predicting the zone of the river over which this would occur, and of course the depth of the scour hole would be greater than the depth of the low flow pattern that could produce holes away from, for example, the outside of a bend.

MR. GENEST: Thank you, Dr. Cooper.

WITNESS HARDY: Mr. Commissioner, the point that this brings up or points up that on one of the cross-sections that Dr. Hollingshead had, he shows the cover at the deepest part of the river only ten feet, then at the shoreline it's 20 feet. Well, this would seem to be incongruous, that you have less cover where you've got the deepest water. The reason for this is that the spot where there's only ten feet of cover is the thalweg that Dr. Cooper has just talked about now, but it may migrate and so the reason Dr. Hollingshead's cross-section shows greater cover away from there is that it's anticipated that thalweg will migrate and may completely cross the normal channel.

THE COMMISSIONER: Thank you.

MR. GENEST: Dr. Clark, is it

time now to turn to the concerns that are related to convection icings, drainage and erosion?

WITNESS CLARK: Yes sir. I think before dealing with this, sir, there are two terms here that might cause some confusion, are the words "conduction" and "convection". By way of illustration if you could consider an electric stove with a burner on, and a pot of water on, there is heat imparted to that pot by convection. Within the pot the hot water will rise to the surface and carry heat to the surface and create currents, and this is convection. To relate that to the pipeline, what is the message here is that when we bury a pipeline, for instance below a river, a frost bulb will develop, heat will flow by conduction but there will also be water moving through that area that introduces a convective heat component.

Now the PAAG concern regarding this --

THE COMMISSIONER: Q I didn't assimilate that.

A Well, the conduction in the analogy that I used relative to a pot on a stove, there is heat passing through the metal into the water and that is conduction.

Q D-U-C-T, I think that's my trouble.

A Conduction, yes.

Q Conduction, I sometimes understand conduction.

A the heat then, as the water heats up it will rise to the surface and move around and the moving water then transports heat, and that's convection, and in a pipeline situation we have the reverse. We have a heat sink, cold heat moving from the ground to the pipe, that is conduction. But when a river is involved there's water flowing, there's a current flowing above the bed and perhaps in the bed, and that's bringing heat in as well, and its that component of heat that is convection. That's the flowing water that's equivalent to the flowing water in the pot analogy.

MR. GENEST: Q Can I see if I understand that? One type of heat which is the conduction heat, is transmitted, it's heat transmitted through a stationary material; and the other is heat transported by moving material?

A Yes, by the water.

Q Is that another way of putting it?

A Yes. The difference between conduction is convection, and convection is heat that's transported to the freezing front, if you like, by the water.

The PAAG concern is that convective heat transfer around a chilled pipeline buried in unfrozen permeable material, on page 175 it's stated that -- and this is on the PAAG Report --

"The applicant has developed a computer-oriented

method for analyzing the ground thermal regime around the pipeline. This method is shown to furnish reliable prediction of the position of the thaw or freezing front around the pipeline for most boundary conditions. The method, however, is limited only to conductive heat transfer and does not include a term for convective heat transfer."

They further state that:

"Convective heat transfer is likely to be a significant factor in determining the rate of growth and ultimate size and shape of a frost bulb around the chilled pipeline where it is buried in permeable soil, having ground water flow. For example in sand or gravel beneath rivers."

They go on to state that:

"It's important that the applicant develop a method of geothermal analysis that will take convective heat transfer into account."

Our response is that we are in total agreement with that and well ahead of receiving this report we had undertaken such -- the development of a method and a method of geothermal analysis that takes convective heat transfer into account has been developed. This is documented in a report entitled:

"A Convective Model for Sub-Surface Flow Around a Chilled Pipe,"

dated October, 1974, by Bettelle.

In general, the effects of convection on the development of the frost bulb around a chilled pipeline are twofold:

1. The convection tends to reduce the size of the frost bulb;
2. It tends to displace it in a downstream direction, and that is, sir, in the direction of the current, the direction of the flow.

Now the magnitude of both of these effects increases with ground water temperature and flow velocity. The effect of convective heat transfer on frost bulb development is shown for three typical river crossing situations in the response to question 38 of the Pipeline Application Assessment Group's request for supplementary information.

Q I don't seem to have that han dy, Dr.Clark. Can you describe them briefly?

A Briefly, sir, they treat a large river with a large amount of flow, a small river with a gravel bed where there is still winter flow, and as well the river which would normally freeze to the bottom and there would be no flow in the bed, all the flow would be in the -- no flow above the bed, all the flow would be in the bed in the gravel, and these are analyzed with this convective geothermal model.

Q The response to question 38 really goes on at quite some technical length.

A It's quite a lengthy response, sir, and it is a fairly technical response to what we felt was an important question.

Q Well then, do I understand your response correctly -- and correct me if I do not -- to the effect, it is to the effect, as I understand it, that the convection, that is the heat taken to the pipe or the temperature change taken to the pipe by moving water, which is the medium through which it's transported, tends to reduce the size of the frost bulb?

A Yes sir.

Q And does that comfort us or discomfort us?

A Well, it's neither, sir. It's the ability to be able to predict this that is of concern. It is a significant component and we feel that the computer model that has been developed will now allow us to take this into consideration. For instance, in assessing the possibility of freezing off a gravel bed to prevent, cause an icing, for instance, or to cut off the water and oxygen that might be required for over-wintering fish downstream, and this gives us the ability now to analyze that situation and when we can analyze it, then if there is a problem we can design a remedial measure for that problem, and I'm getting into the icings discussions that we had yesterday, really.

Q The next concern, sir, related to icings and blockage of water flow above and

below the bed or small rivers.

A Yes sir, and we did discuss that yesterday to some extent, and there is a much more detailed response also included in this question 38,

of our response to the PAAG request for supplementary information.

Q And you have prepared that answer?

A Yes, sir, this was prepare by our expert on conductive heat flow, Dr. Harlan who will be appearing in phase II of these hearings.

Q Then sir, I would like to move on to the Pipeline Assessment Group Concern with relation to erosion and drainage control measures.

A Yes, sir, the PAAG concern, Erosion and drainage control measures. Now, many of the concerns identified by PAAG relate to the appropriateness of a preliminary assignment of erosion and drainage control measures as shown on the alignment sheets which have been filed. It was suggested that the reappraisal of these measures with regard to local terrain type, slope conditions and proposed construction methods, would be reasonable in order to reduce the local susceptibility of the terrain to erosion. Again, we agree with this and it is our intention to review the drainage and erosion control measures, keeping in mind the nature of the terrain, the slope conditions and the method of construction. We would emphasize however, that the selection and placement of drainage and erosion control measures as appropriate to a given section of the pipeline alignment and to associated ancilliary facilities such as the roads and airstrips,

is a final design exercise. The design procedures are being refined by office, laboratory and field investigations. Guidelines will be provided for field implementation and this would be contained in the data design manual to which I referred yesterday. Now it is obvious that the final selection and placement of alternative control measures must be made in the field prior to and during construction.

Further, a program of regular surveyance and maintenance is planned to correct any problems should they develop in order to maintain the effectiveness of the control measures.

In addition it is pointed out that the purpose of the drainage and erosion control measures is largely to protect the pipeline right-of-way and the other facilities for the critical period until revegetation can be established. Now, in the final analysis our main erosion control measure is revegetation.

It is recognized that there will be situations, however, where the physical measures that we have developed will be required in addition to revegetation. It will be necessary to provide long term erosion control for instance on slopes. Now, with your permission, Mr. Commissioner, I would like to illustrate and it will not be a lengthy one, I have only a few slides. Some of the erosion control measures for which we have prepared drawings -- and I rely here

on a report that was tabled last week. "The drainage and erosion control measures, description and proposed design principles." What I would like to cover sir, are the actual design, how they would look in the field and how they would be placed.

The aspect of drainage and erosion control which relates to predicting flow and gathering the data required to predict flow, we have viewed as being pertinent to the section of panel two or phase II rather, dealing with impact on water and our erosion control expert that we would call in that instance would be Dr. Harlan, so he can speak to the -- what is entitled in this report, for instance, the design philosophy for the pipeline right-of-way and I think I would speak to the designs as to how they would be -- how they would appear.

Sir, this is a schematic drawing of a section of right-of-way with sloping ground. The ditch has been dug, the pipe is placed in it, the back fill has been restored over the ditch. Now, when the pipe is placed in the ditch itself, it will occupy a space formerly occupied by approximately 12 cubic feet of soil for each foot of length. Also by the process of digging ou t the soil, it would occupy a greater volume after it has been excavated than it would before and this results in what we call the spoil mound. All of the back fill is placed over the pipe and it would have a configuration somewhat like this, to what

we have referred to primarily as the spoil mound and also is sometimes called the berm over the pipe.

Now, our main objective then relates to transferring surface water from one side of the spoil mound to the other on the slope and to prevent the spoil mound from eroding away. The techniques that have been developed include predominately those that are used in conventional pipeline practice, for example, the diversionary dike that would be placed along the slope and at that dike a break in the back fill mound which would be protected by a nonerodable soil such as gravel and in this situation water flowing across this slope would flow along the back fill mound, spoil mound, through the break, across the right-of-way and would be dispersed on the other side of the right-of-way.

Next slide, please.

The type of diversion dike that would be used would be a mound of non-erodable soil placed directly on the organic mat where the sub-soil is a high ice content material and this is a cross-section through that mound.

The next slide, please.

In the situation where the soil is not a high ice content material, is relatively stable, the diversion dike would be formed by digging a small ditch on the up slope side, mounding it to form the dike and then placing in that ditch granular material which would be resistant to erosion by the running water along the ditch, that is, if that soil, the native

soil here, is erodable and requires that protection.

Next slide, please.

Now, looking at the cross-section of the ditch and particularly at the spoil mound where water is required to run along it, as I said, it is a requirement to keep from exposing the pipe to insure that this native back fill material does not erode. THis would be accomplished by placing a granular protection face along the upslope side. In this situation the water would be running from left to right, it would encounter the spoil mound, it would then run along the spoil mound until it had an opportunity to get through the back fill mound break.

What we have shown here is a position of the permafrost table with the configuration before the line goes into operation. After the line goes into operation there will be a bulb of frozen soil above the pipe and of course, during winter the entire active layer in a situation such as this would be frozen. However, in the summer period our test sites have shown that there is always an active layer above the pipe. It does not remain frozen off through the summer. The configuration of the permafrost table in the summer would come to the ditch and then curve upwards over the pipe, then down and away and this material directly above that would be unfrozen and would be able to conduct water.

The next slide, please.

Now, in areas where there are a number of very closely

spaced drainage channels or where there is a great deal of flow through the active layer, one measure of providing for both protection of the native back fill material as well as the conduction of water across through the mound, is to use a granular cap. In this situation the cap is both resistant to flow -- resistant to erosion and will conduct flow. There would be a revegetation medium put on top of that and it would ultimately be revegetated.

Next slide please. NOw I talked about the breaks in the berm in the first slide. -- And where those breaks occur there will be concentrated flow and it is also necessary to provide an erosive resistant material at those breaks. This would consist of gravel from a short distance above the pipe to the ground surface, it would be carried through as far as required to protect the native soil from erosion and it would have some form of rip-rap to break up the concentrated flow and disperse it on the downstream side. Again, flow here would be in this direction.

Next slide, please. There are several alternatives, methods available to accomplish this. One where for instance, if gravel were not available in the quantities required where we had a lot of closely spaced mound breaks, it may prove both convenient and economical to use what is called a gabion over the mound break. This gabion is simply a mesh of wire which has gravel or broken rock in it to hold it in place, it may be of

somewhat finer material, the wire assists in preventing erosion and it also requires a lesser thickness and any subsidence of the soil adjacent to the pipeline in the active layer would be followed by this gabion, it would take the shape, it is not a rigid structure, it is very flexible, erosive resistant material.

Next slide, please.

This is looking down on a pipeline right-of-way where the pipeline itself is running oblique to the sloping ground. That is, the ground is sloping across in this direction. Now, in this situation, the diversion dikes are carried across the entire width of the right-of-way. At the breaks in the spoil mound the water is allowed to pass through, carried across the right-of-way and then dispersed on the downslope side of the right-of-way.

Now, if it is necessary to prevent water running along the pipe, a ditch plug would be put in at each of these mound breaks and I have some illustrations of the type of plug in some later slides.

The next slide, please.

This represents the situation where a pipeline is running directly down the slope and this is the configuration of diversion dikes that would be used in that situation or where the pipeline is within about plus or minus 10° of the direction of the slope.

This would be a diversion dyke taking flow coming in this direction and transporting it to the side of the right-of-way and dispersing it in this area. Now in this situation we would definitely want to prevent erosion of the backfill that has been placed over the pipe and this is accomplished by putting in impurvious plugs. The next slide, please.

This is an example of the type of impervious plug that could be used. This could be soil placed in sacks piled in a configuration such as this, keyed into the wall of the ditch to ensure that the water would not outflank it. The key word here is that this should be impervious. There are other methods of constructing this. For instance, it could be a bentonite enriched soil placed back around the ditch in a similar configuration, and bentonite is a clay that is actually produced in powder or small nugget form that's used in the oil industry for drilling wells as a drilling fluid. It has the characteristic that it expands when it comes in contact with water and has a very,very low permeability and prevents water flowing through it.

Now perhaps I could show my final slide, which would illustrate some of this in place. This is a gas line, the same gas line that Dr. Hollingshead referred to when he showed a picture of the bolt-on and continuous concrete weights. These are plugs, sack-breakers or impurvious plugs that are

put along the slope to prevent the soil that is placed back into the line from being washed out by erosion. This is probably the most common technique and in certain situations it would be possible to use a -- several types of impermeable backfill ditch plugs.

Those are some of the designs, sir, that are mostly illustrated in the report to which I referred. Thank you.

THE COMMISSIONER: That last slide, is the 12-inch pipe somewhere near Trail, British Columbia?

A Yes sir, this is near the Columbia River. It's Inland Gas line.

Q Could I ask a question of Dr. Cooper? You showed us some slides of an ice formation. I think you said it was south of Point Separation.

WITNESS COOPER: That's correct. That was some slides of an ice jam that we observed in the 1973 breakup.

Q Yes. That would be the crossing of the prime route north of Arctic Red River, would it be?

A That's correct, sir.

THE COMMISSIONER: O.K., thank you.

MR. GENEST: Sir, that concludes my examination in chief of this panel. It's been a difficult one for counsel to try and organize

because of the technical nature. We had our rocky roads. I don't think that the interjections by Commission counsel and by you, sir, as to simplifying and explaining were the stern warnings -- at least I did not interpret them as referred to on news broadcasts this morning. I hope it has been useful and perhaps as we go along we can learn how to strike the middle road between exact scientific accuracy, which involves the use of jargon, and an understandable presentation of evidence. that concludes my examination in chief.

THE COMMISSIONER: Thank you, Mr. Genest.

CROSS-EXAMINATION BY MR. HOLLINGSWORTH:

Q Dr. Morgenstern, I was interested in some of your comments on seismicity and I've had an opportunity to read from Exhibit 54, the location, design and capacity of facilities, and in particular from the geotechnical section on page 14. There reference is made to the Guttenberg and Richter surface wave magnitude scale and a little further down to the Richter local magnitude scale. Is there a difference between those two scales, sir?

WITNESS MORGENSTERN: I don't have the reference here.

Q Page 14 of 8-B-3, Mr. Genest. The reference is in the third paragraph on page 14, sir.

A Yes, the Guttenberg-

Richter scale and then the other reference you said?

Q A little further down in that paragraph there's a reference made to the Richter local magnitude scale.

A Yes, I believe there is a slight difference in the two scales. The detailed explanation requires a greater knowledge in seismology as opposed to earthquake engineering. Both are used -- both can be used for zoning.

Q Could you perhaps give us a brief explanation of first the Guttenberg and Richter surface wave magnitude scale? On what scale does it start from? Where does it go to? How many numbers are there in it?

A Yes. It goes to -- it's a measure of the energy released by an earthquake. It's based upon seismilogical observations. The magnitude -- oh, theoretically I think the maximum magnitude that an earthquake would have, would be in the order of 9 or 10, the magnitudes begin at very low numbers in the order of 1 to 2. The difference in the scale reflects about an order of magnitude factor of 10 in the energy release of an earthquake. An earthquake of magnitude 5 in comparison to an earthquake of magnitude 6 would have about a factor of 10 less energy release.

Q I'm not quite sure I've comprehended that. Are you saying that 10 is the maximum figure to which you could -- which an earthquake

could achieve?

A There is a theoretical maximum of energy that can be stored in a volume of rock that would constitute an upper limit of magnitude.

Q And would that be 10 on the scale?

A I can't remember whether it's 10, sir, but it's of that order. The largest earthquakes, great earthquakes, very destructive earthquakes such as the Anchorage, Alaska -- such as the Alaskan earthquake of some ten years ago, had a magnitude of around 8point something or other.

Q And what would the physical effects of a magnitude 10 earthquake be?

A A magnitude 10 earthquake would be very catastrophic.

Q Does that mean a total breaking up of the earth's surface in that particular area?

A Large-scale faulting, large-scale displacements over very large lengths.

Q And --

A I would add, I think, to my memory a magnitude 10 earthquake has not ever been recorded. We're talking of earthquakes of smaller magnitude than that, normally recorded.

Q Armageddon of earthquakes.

A Well, of theoretical earthquakes.

Q And the local magnitude scale referred to lower in that paragraph, how would that differentiate from the surface wave magnitude scale?

A. It's based on a similar measure of energy release, but the use of the data, the seismic observation used to interpret magnitude differs from the surface wave observations. I would add that this is an area of seismological definition and I'm only reciting from general memory. I don't establish earthquake magnitudes.

Q Now, this measurement which is referred to in this paragraph, perhaps I should read it, it says:

> "Historical records indicate that an earthquake of magnitude of 6 1/2 on the Guttenberg & Richter surface wave magnitude scale occurred some 30 miles west of Fort McPherson in 1940."

Then it goes on. Where would that measurement have been made from?

A That would have been based on seismological observations collected by various observatories. The seismological observations not collected locally, some distance away, I can't remember where the network existed in 1940,but you could record these observations hundreds of miles away and interpret the general level of energy release in that area.

Q Is this general practice in North America, that these stations are well-spaced?

A The spacing changes with time as networks improve. In -- at the time of 1940, one would have been relying, I expect, mainly on stations under the control of probably the United States Coast Geonetic Survey. The network in Canada would have been sparser.

Q Where would such United States stations have been?

A Oh, any number of places in the United States, as far away as Southern United States, could still collect information on the earthquake recorder that could be used to interpret the magnitude.

Q Would it be fair to say that the accuracy of such readings decreases the further one gets from the actual centre point of the earthquake?

A No, not so. The accuracy decreases the fewer the number of stations utilized to collect the earthquake, to sense the earthquake. The difference in accuracy between 1940 and 19-- today, is that there are more stations spaced around the world.

Q But you wouldn't know how many stations would have measured this particular earthquake that's referred to here?

A No, but it would be on record, seeing what the world wide networks were at that time.

Q So that it's possible

that there were very few stations, or even one station measuring this earthquake in1940.

A No, no. In order to site a magnitude, one would have had also to locate the -- at the centre of the earthquake -- one would have had reasonable number -- a substantial number of stations reporting on the earthquake. You can't undertake these calculations without a certain number of stations recording. You need more than one station, for example, to pin-point the general area of the earthquake.

Q Well, going back to the type of trauma that would develop from a certain scale earthquake, this one reached 6 1/2. What sort of magnitude does that indicate in terms of physical damage, if you like, to the earth's surface?

A It depends also on the depth of focus of the earthquake where the centre of the faulting is. The damage is the function partly on the amount of energy released and also the depth of focus of the earthquake. For example a rather shallow, if the faulting or energy release occurs at a rather shallow area, it would localize damage closer to the epicentre for a given magnitude or energy release. If the depth of focus is greater, then the damage would be less, but the sensing of the energy release would be over a greater area. The intensity of damage would be less localized and the level of damage would be smaller. So there are several parameters involved in assessing the inference of an earthquake, the magnitude is not the only one. Nevertheless, the larger the magnitude, the tendency greater damage.

Q All right. Now, on this same page that I have been referring to in the fifth paragraph, the last sentence states, "However at the present time there are no faults along the pipeline route that are known to be active." -- and a reference is made to Stephens Mill, 1973. How is an active fault as opposed to an inactive one if there is such a thing defined?

A It can be found in two ways, by geological evidence, one sees rivers that have been forced to change their course dramatically and then you look at the rock structure and identify a tear in the rock and relate that geomorphological evidence to the activity of faulting and the other is

to utilize local seismic evidence, local seismic data.

Q Well, would I be correct in suggesting that evidence of earthquake activity going back many, many years can be found in several places on the face of the earth?

A I am sorry -- I --

Q Would I be correct in my assumption that evidence of earthquake activity going back many, many years can be found in several places on the surface of the earth?

A Oh, yes.

Q Is that considered an active fault?

A The activity -- what we consider an active fault when we see it tearing the ground. Things are happening down below the surface of the ground that need not be expressed at the surface of the ground. Now, while that would be a concern for the general energy release, if we do not actually see the ground tearing, then we do not see an active fault related to that energy release.

Q And if no evidence can be seen on the surface of the earth is it considered inactive?

A If we do not find an active fault, then we say that so far all the faults we see are inactive.

Q And is it a period of

centuries that one -- that a fault goes from being active to inactive?

A There are certainly inactive faults can become active, but normally if there is active faulting, there should -- usually one finds some geomorphological evidence associated with it. --Because the response of rivers and these other agencies in the environment have been responding for a long time.

Q But is it possible for an inactive fault to suddenly become active?

A Yes.

Q Given the design parameters for the Interior Route, are you satisfied that all steps have been taken so that no faults could occur in the line, no break could occur in a line in the event of any earthquake activity in the Richardson Mountains?

A Yes, the line has been designed to accomodate, the interior route, very large earthquakes for that matter and also a configuration has been recommended to accommodate active faulting in the event that the line did traverse an active fault .

Q Are you saying sir, that you can guarantee that no break would occur in the line in the event of any earthquake?

A Well, I am saying that we have implemented design measures that accommodate very substantial earthquake activity. That is

perhaps not my guaranteeing -- These have been the design recommendations.

Q So in other words it would be fair to say that a break is still possible, notwithstanding your best estimates and designs?

A The best estimates anticipate or take into account very large earthquakes. The design criteria have been recommended on a conservative basis and employed in a conservative basis.

Q But nevertheless a break is still possible, is it not, Dr. Morgenstern?

A In the event of an earthquake that is unprecedented in our considerations, one might speculate on that.

Q Is there any advantage to twinning the line through potentially active area in order to avoid breaks?

A I see none at this time.-- Unless one had well identified active faulting which you could rationally choose to do that. If you could identify where your concern for breaks rise, you might consider that.

Q Okay, and something else that interested me, on page 15 of that material, Dr. Morgenstern, there is talk of considerations taken into account relating to buried pipe -- that is about two-thirds of the way down that page and perhaps if you might read sub-paragraph A. It starts:

"In the zone of highest seismic risk ...."

A "In the zone of highest seismic risk, where thereis a possibility of fault movements and if the main line pipe is buried in bed rock, the ditch will have a minimum depth of burial and the walls will be sloped. The ditch will be back filled with non-consolidating granular material".

Q When I read that I was speculating as to what this accomplished. Perhaps you could fill me in.

A Yes, in the event of an active fault which we might regard as a scissor action attacking the pipe, we would like to allow the pipe to jump out of its ditch and react flexibly on the surface instead of being trapped by the scissor action of the moving rock and therefore this configuration is recommended so that movement out will not be impeded.

Q Fine, thank you.

Mr. Williams, this is something that came up I think on Monday. I was unable to find a reference to it -- it is perhaps outside the terms of reference of this panel, but nevertheless it has been brought up in Mr. Genest's evidence in chief. You gave evidence that there was to the best of your knowledge, 48" pipe in service in this country?

WITNESS WILLIAMS:

A I think I said that

part of the Interprovincial -- that it was my recollection that part of the interprovincial system had 48" pipe, yes.

Q Do you know where on the Interprovincial system that is?

A I thought there was some in Manitoba and maybe extending into the lakehead system south of the border.

Q Could you find out for me where it is, sir?

A I can, yes.

Q Thank you.

MR. GENEST: Mr. Commissioner, I have some trouble with that kind of question. This is, -- well, perhaps I am making a fuss about it, but there's nothing else that we can do about it, but it seems to me, sir, that we ought not constantly to have cast on us an obligation to check out an answer like that given by Mr. Williams which went no farther than to say it was his impression that there was. Now, Mr. Hollingsworth has had identified for him -- he can surely check that on his own if he has got contradictory information, otherwise we will have these witnesses coming back all the time.

THE COMMISSIONER: It is an oil pipeline that you are talking about, is it not?

A That is correct, sir.

MR. HOLLINGSWORTH: WEll, Mr. Commissioner, my point was that you brought it

up yourself in your questions and I think that the question went to the type of experience that might have been occasioned with 48" pipe and if in fact there is no 48" pipe, then I think that is relevant to the question that you put to the panel, to Mr. Williams.

THE COMMISSIONER: Yes, I think it is relevant, Mr. Genest -- the witness said that he could find out for us.

MR. GENEST: All right.

MR. HOLLINGSWORTH:

Q Dr. Cooper, I think I should address this to you. The problem of scour. I assume that this is a long recognized problem with respect to pipelines?

WITNESS COOPER:

A I would not necessarily call it a problem. It is a phenomona that has long been recognized.

Q It is something that must be taken into consideration with pipelines, is that so?

A Certainly.

Q And it has been long recognized as such, has it?

A No, it has not. IN fact many of the pipelines that have been built in North America have not, to my understanding, had design input in the area of river engineering.

Q Well, can you tell me

how recently it has become more of a consideration, if you like?

A I think as a result of Dr. Hardy's work. I know in Western Canada that Dr. Hardy has involved Tom Blench, Dr. Tom Blench with our firm in the design of certain major river crossisngs in Western Canada over the past 20 years.

WITNESS HARDY:

A Would you like me to enlarge on that?

Q Yes, if you would, by all means, Dr. Hardy.

A I know this to be the facts of the situation, that back in 1948 we at the University of Alberta in collaboration with the National Research Council, attracted to our staff in Civil Engineering, Dr. Tom Blench who had spent 20 years or 25 years in India and Pakistan. He was available because of the change in government there. He was an expert in river hydraulics, you see, and he has made a very great contribution, not only in Canada, but on this continent.

Now, it was shortly after that that I became involved with the geotechnical problems on the Trans-Mountain Pipeline and that was the first major pipeline, trunk pipeline in Canada where -- well, it was one of the earlier trunk lines anyway, but it was certainly the first in Canada where any geotechnical input had gone into the

design and it was one of the first on the continent where any geotechnical input had gone into the design. WEll --

Q Excuse me, what date was that,sir?

A In 1952 -- give or take a year there.

THE COMMISSIONER: That was an oil pipeline?

A It was an oil pipeline.

Q Was it buried or above ground or above ground or both?

A It is practically all buried, but it did have one or two locations where there were short stretches that were above ground. Followed by that of course was Westcoast, where they had a number of so-called overhead crossings, but not above ground constructions such as being used on Alyeska, for example. While in the process of doing the geotechnical studies to the extent that they could be done on a one man operation, these river crossing problems came up and I introduced Dr. Blench to these problems.

The Trans-Mountain was the first system on this continent, I'm positive of that, where the expertise that he had was applied to pipeline crossing design, and it was new to the industry, and we have in Canada, you see, as a result of his work, as a result of his publication, a result of his students, we have -- I think this is absolutely fair to say, that the standard of expertise that applied to the pipelines in Northwestern Canada in that area has been of the highest standard of anywhere in the Western World. The information was spread from Canada to the United States and Dr. Cooper's involvement with Aleyeska came about first of all through the approach from Aleyeska to Blench, and people such as the Bechtel Corporation who have done widespread pipeline construction, or the engineering for it, also the construction in the Western World, they were aware of him because they were doing the engineering on the Trans-Mountain. So that it's not correct to say that it's a routine standard problem and that it's very old. That is the history of it on this continent, and we in Canada have made a very substantial contribution to the level of expertise and there is none better. I'll challenge you to prove that to me, sir.

Q Dr. Hardy, I'm not arguing with you. I'm just enquiring as to how far back these considerations go, and you indicate to me that they go back to the late 1940's, which is now what?

A 1952. Blench brought him here in 1948.

Q So it's a 23-year period.

A That's right.

Q Which is a considerable period of time, and when this design for the Mackenzie Valley Pipeline first came across your desk, were you aware that the problems might be somewhat greater with scour in this part of the country?

WITNESS COOPER: A Generally we did not anticipate that the problems with respect to scour would be greater, for most of the events that we have to deal with. The one exception to that, of course, is the scour related to ice jaming in the Mackenzie River, and the crossings of the Mackenzie River.

Q And were you aware of such scour damage at the time this assignment, if you like, first reached you?

A We were aware that the process would have to be considered. There had been at that point in time,to the best of my knowledge no observations of scour occurring during the formation, development and release of an ice jam.

Q And when did you first come onto this assignment?

A I might have to check the record on that, I believe it was in1970 or '71.

Q And has twinning of lines been recognized as the ultimate or a cure for any breaks that might occur as a result of scour?

A I think my answer to that, my impression on that is that from an engineering viewpoint I do not believe that it is necessary to twin the line . I believe that the same level of safety, if you like, can be achieved on those crossings where the lines are being twinned, as can be achieved on the crossings where the lines are not being twinned.

Q Then you're saying there's no advantage in twinning whatev er?

A The only advantage would be that in the very low probability event of a failure, the access for repair of that failure.

Q How far apart would these lines have to be to be of any advantage?

A This of course would depend on the cause of any break that might occur. On one hand, the cause could be possibly due to some sort of a structural defect, in which case the separation would have no bearing at all.

Q Well, let's assume it's because of an ice jam which has scoured down and bashed in one of the pipes.

A That is not what occurs. If an ice jam occurs, we do get scouring and in the event that we get scouring such as we got exposure of the pipe, not to the bashing of ice but to the hydraulic forces of the flow of water.

Q You can see I'm not an engineer.

A Then on the basis of my analytical work, I feel that the twinning or the separation would have to be in the order of several river breadths, certainly no more than that. Our work indicates that the maximum scour occurs when we have an immediate thickening of the jam to the point where it is marginally stable due to the forces acting on it. Then we get essentially a cut-off of the ice supply to this jam, such that scour can develop to its full extent, that is to the thickness of the submerged portion of the ice jam itself, scour can develop to its full extent over the entire length of the ice jam. Then we are talking about the need to separate the two crossings at some distance greater than this rather short ice jam, which would result in maximum scour. I believe that several river lengths would be more than adequate for this critical condition.

Q I believe you mean river breadths.

A I'm sorry, river breadths. I hope I don't mean river lengths.

Q Is this a formula that's been worked up over the years as to how many river breadths you should have to ensure this, is there any relationship between the breadth of the river and how long an ice jam will be there?

A No. The work that has been done on this project to analyze the scour beneath

an ice jam or associated with an ice jam has involved some pioneering work, if you like. What we have had to do is take the equations for flow and merge them with the knowledge on the development of an ice jam and again input the knowledge and equations that predict the amount of sediment that would be transported under various coniditions. We then come up with an analytical model of the entire process which we would use to predict scour and to predict how the ice jam would grow, how scour would develop in the event of this growth. This has been work that had to be done directly as a result of this project.

Q Have you been involved with the applicant's plans to twin certain river crossings?

A Not in any specific detail, no.

Q Are you aware how much separation the applicant plans at any given river crossing?

A You better answer that.

WITNESS HOLLINGSHEAD: The suggestion in the preliminary design is approximately one river width. I might add that these preliminary designs, as they exist in the exhibits on the record, are based on open water flow conditions, that is not related to an ice jam.

THE COMMISSIONER:

Q Dr. Hollingshead, just before you leave that subject, the cross-delta route is twinned from the west side of Shallow Bay

to Richards Island -- it's hard to tell on this map but it appears to be for a --

A It is twinned for about 35 miles, sir.

Q Well, when you -- how is the width, or at least how is the distance between the two pipes determined for purposes of that crossing of the Mackenzie Delta?

A Yes sir, well as I recall there's about 35 miles of the dual pipeline on the cross-delta alternative. The overland portions of that separation is 50 feet, which is primarily a construction restraint. The portion across Shallow Bay is a 200-foot separation which is again, just a nominal separation. The two major channels, which are left, prior to the junction that is Langley Island Channel and North Arm Reindeer Channel, again the separation is approximately one river channel width. Similarly the twin crossing of east channel which is proposed is again one channel breadth, nominally. That is some 3,000 feet. I might just add that our observation data and judgement is that there is no real possibility of a ice jam developing at points along that cross-delta route.

Q Well, if the crossing of Shallow Bay were -- the two pipes were to be separated by the width of the river, so to speak, it would be very much greater -- the two pipes would be a very much greater width apart than 200 feet.

A That's right, sir. In

fact, in the Shallow Bay region we do not anticipate difficulty really either from scouring in general with or without an ice jam, primarily because the delta is a net depositional environment. There is no evidence of deep scouring in the vicinity of the line, and again the separation there is just a nominal 200 feet.

Q Well, why -- I know somebody else sought to answer this in the panel we had last week, but without asking you to go beyond your own field of competence, why are you constructing twin pipes under Shallow Bay, which is, so far as I can tell, the widest river crossing in the whole system? The widest water crossing, the widest body of water that you have to cross.

A Yes sir, really it's a question, I believe, of cheap insurance in the event of a break from some other cause and the point being that in order to get in and replace a line under the conditions which may prevail, considering a break at the worst time of the year, that is during breakup, when you have a high water condition, you're out of service for a very significant period of time and it's insurance against that that the lines are dualled.

Q Well, if there's no danger of a break owing to scour or to an ice jam, then what are the other dangers against which you are seeking to insure yourself? If you're able to say, I don't want you to go beyond your own field, sir.

A Perhaps Mr. Williams may wish to speak to that.

WITNESS WILLIAMS: Failures in pipelines can result from other reasons, for metallurgical problems, failure in the steel itself. Usually this is initiated by a small scratch in the pipe that occurs during the construction processes and certainly historically there have been failures at these locations, where a small defect occurs in the pipe. They are few and far between, but they are -- they have occurred and in Shallow Bay, a failure of that nature would result in a prolonged shutdown.

Q Are there any other reasons for twinning a pipe that you can give me? You mentioned the possibility of a failure in the steel itself. Are there any others that come to your mind? If this is going to be dealt with at length later on, I don't want to press you, but it has come up and if you'd like to enlarge on that answer you just gave, please do.

A No, I don't think I can say anything beyond what Mr. Dau said originally. It is insurance, it is -- there are -- the risks are very minimal but the consequences of a failure are

very high.

MR. GENEST: Was not your question, sir, directed to other causes of failure? I don't think Mr. Williams answered that.

A I can't off the top of my head think of another reason, other than the metallurgical situation that I mentioned, Mr. Genest.

THE COMMISSIONER: Well, excuse me, Mr. Hollingsworth.

MR. HOLLINGSWORTH: Well, if I may direct a couple more questions in that vein to you, Mr. Williams. As I understand it, the line coming along the coast to go over Shallow Bay is now either 48 or 42 inches, is that right? Depending on the alternate use.

MR. GENEST: It's now 48 inches, Mr. Commissioner. We filed -- we are applying for a 48-inch pipeline, we're asking the Commission to look at 42 inches but the present state of affairs is that it's 48.

MR. HOLLINGSWORTH: Well, it's either 48 or 42, depending on what's convenient, Mr. Genest.

THE COMMISSIONER: Well, 48 now but watch for revelation.

M R. HOLLINGSWORTH: It then goes into two 36-inch lines to cross the delta?

WITNESS WILLIAMS:
A Yes, that occurs west of Shallow Bay. It takes into account there is a

dual crossing that crosses a small channel to the west of Shallow Bay, I've forgotten the name of it but it's a few miles west of Shallow Bay where the Dual Line starts, yes.

Q And is it fair to say that it's going from a large diameter 48-inch line into two 36-inch lines because those two 36-inch lines can accommodate all the gas coming through the 48-inch line?

A That is correct.

Q So they don't need to be any bigger, if they're twinned they don't need to be bigger than 36 inches.

A This is if both 36-inch lines are in operation, they have a capability of transporting about the same quantity of gas as one 48-inch line, yes sir.

Q And if you have a river crossing further south, for instance, that's twinned, will the twinning line be 48 inches as well as the main line?

A That's what we have shown in our application, twin 48's I think at four major river crossings.

Q And will both those lines be in operation, or only one at a time?

A That option is open. It's not fixed, it doesn't have to be fixed.

Q So you could use both 48-inch lines at once?

A You could operate in that mode, yes.

Q And you have a crossing handy in the event you had to twin your 48-inch line all the way down the valley.

A That was not part of the consideration of twinning the crossings, no sir.

Q But it nevertheless would be handy, in the event you did build another line.

A I can't say that. If you were going to twin the line you might want to put in two more 48-inch crossings.

Q Dr. Hollingshead, dealing with buoyancy, if we might. As I understand it, we're talking 48-inch pipe which is about 3/4 inch wall thickness, and can you tell -- excuse me, sir, can you tell me if this is more buoyant pipe than a smaller diameter pipe?

WITNESS HOLLINGSHEAD: I'm not familiar with ~~the range~~ of wall thicknesses of various diameter pipes so I suppose you could have both possibilities. In fact, the river crossing pipe is not, as you referred, at this stage, it's not shown as 3/4 inch. I could be corrected.

Q Let me assume a standard wall thickness. Can you give me a ratio of buoyancy between a 48-inch line and say a 36-inch line?

MR. HOLLINGSWORTH: I'm assuming the same wall thickness, sir.

WITNESS WILLIAMS:

A In the same wall thickness the 48-inch would be more buoyant than the 36.

Q I'm wondering how much more? Twice as much?

A I don't know, I don't have those numbers at my fingertips.

Q Would you know, Dr. Hollingshead?

WITNESS HOLLINGSHEAD: No sir.

MR. HOLLINGSWORTH: Mr. Commissioner, I see it's 12:45. I don't expect I'll be that much longer, but these things do have a tendency to drag on longer than lawyers ever estimate; perhaps you'd like me to continue tomorrow?

MR. SCOTT: The reason I asked my friend the question is because Mr. Mercredi wishes to make a short submission, and it would be helpful to do that before lunch today, if that could be arranged.

THE COMMISSIONER: Yes. I should say that this Inquiry is going to visit each community in the Mackenzie Valley, the delta and the Northern Yukon likely to be affected by the construction of a pipeline and corridor development. I don't want anyone to think that to be heard by this Inquiry they must journey to Yellowknife from their homes in the valley or the delta or Northern Yukon. The Inquiry

will be in these areas.

MR. SCOTT: I discussed that with Mr. Mercredi and he made it clear to me and I'm sure he'll confirm it to you that he will not be present at the community hearing at Fort Simpson and will not therefore be making any submission there, and he therefore asked that he should be allowed to do so today. In view of those circumstances it seems to me that perhaps he should be heard, if this is a convenient break for my friend.

MR. HOLLINGSWORTH: It appears it is.

THE COMMISSIONER: So if you will give way to Mr. Mercredi, certainly I'll be happy to hear Mr. Mercredi's --

MR. SCOTT: Perhaps, Mr. Commissioner, the panel could be excused. There is nowhere else to sit.

THE COMMISSIONER: Yes.

(WITNESS ASIDE)

MR. SCOTT: I take it it's not necessary to have Mr. Mercredi sworn.

THE COMMISSIONER: Well, Mr. Scott, what do you say? Should he be sworn? I'm in your hands.

MR. SCOTT: I think, Mr. Commissioner, it will depen d on the course of conduct that is to be utilized at the community hearings. I think perhaps sworn evidence is no worse than unsworn

evidence, and perhaps to protect us against future eventualities the witness should be sworn.

THE COMMISSIONER: All right. Miss Hutchison, would you swear in Mr. Mercredi?

JOSEPH GERMAINE MERCREDI,
sworn:

THE SECRETARY: Please state your full name.

A Joseph Germaine Mercredi.

DIRECT EXAMINATION BY MR. SCOTT:

Q Please carry on, Mr. Mercredi.

A My name is Joseph Germaine Mercredi, and I'm from Fort Simpson, Northwest Territories, and I'm also the editor of the"Mackenzie News".

I hope I didn't interrupt anything that was very important, Mr. Commissioner, because I feel that at this time I have to submit a submission to this Commission that would sort of bring some sanity to the boring type of policies that I've been hearing since -- and reading in the papers. So I'll start into my submission, if you don't mind.

I don't know how many times I've heard or read the Federal Government statement about its priorities for the north. They are repeated like a phonograph with a scratched record. The government's priorities for the north are as follows:

1. Development of northern people in line with the kind of life they want to choose;

2. Protection of the environment.

3. Development of the natural resources.

How often has the Minister stated that the natives will have free choice in the kind of life they wish to choose, or lead? How often has he said that those natives who want to work for wages will be assisted to do so? And that those who want to live close to the land will be assisted to lead the kind of life they want.

This northern development policy, this set of priorities has been approved by the Federal Cabinet, it has been tabled in the House of Commons, it has been stated on a thousand lecture platforms -- "People First." Then the natural environment, the mineral developmen ts, those are the priorities that the Government of Canada has promised the people of the north and the people of Canada. Nobody would have the kind of suspicious nature that would make him doubt the sincerity of these statements. Who would be as cynical as that? Who would doubt promises

made by the MInister of NOrthern Affairs and by the privy council of Canada.

Most of us natives in the NOrth believed the MInister and the Government of Canada. We certainly wanted to believe them, we wanted to believe that for once the North would not be treated like a colony -- like one of those banana repulics in South America. We wanted to believe that the Government of Canada would act straight with the Native people. We wanted to believe that for once the bureaucracy would follow policies laid down by the Parliament of Canada. I certainly believed the promises made by the Minister and the Government of Canada and it is well known that if Joe Mercredi believes something then anybody can believe it.

We wanted to believe that the Government promised because it is our lives, our future are the stakes in this poker game. Everybody knows that in the past twenty years Government policy has taken the Natives off the land and put them in settlements in the Mackenzie District. Everybody knows that the pipeline construction is a boom-and-bust business. 7000 men at work this year and 150 next year. We thought what the Minister was promising was this: if we, the Natives, wanted to build an economy that did not depend absolutely on oil and gas and the Maceknzie Highway, the Government would help us to do this.

That seems to be a fair trade. The people of southern Canada get 500 billion

dollars worth of oil and gas. We,the Native NOrtherners get some help in building up a decent, permanent way of life. Canada gets what it needs. We get what we need, that is fair enough.

If the people of Canada get $5,000 worth of minerals for every dollar they have to spend helping us, that is fair enough also. We are the people of Canada just like everybody else is, except we have a special interest in the North. We live here. We like to live here, and we are going to keep on living here.

Now, I just want to say again how much faith I had in the Government. HOw I .believed the Minister and the Cabinet when they said so often that their first priority was development of the people of the north according to their chosen way of life.

Now, everybody knows that a lot of research has been done to help the Government of Canada set up the programs to follow through on the Government's priorities.

Research to help the northern Natives develope a decent kind of life.

Research on the environment.

Research on mineral resources and how to exploit them.

I have in my hand here a book which describes 18 million dollars worth of research mostly done by the Federal Government, a lot more than that was spent by the Government.

This here was mostly in 1970 and 1971, and maybe an equal amount was spent by Canadian Arctic Gas Study Limited and the companies that make it up.

But this list of 18 million dollars worth of research projects is plenty to give a good idea of the kind of informaiton the Government was looking for.

There were 175 research projects altogether. They cost an average of $100,000 apiece. A total of almost 18 million dollars.

Now, if anybody was setting up research to help native people live better in the country, what would theybe thinking of? I guess they would worry about good housing and how to build it at a low price. They would be thinking about country food and how to get it and get it onto the people's tables at a fair price. They would study how to get small industries going so we could make what we need, and not have to let all our cash go out of the country.

You could make a list of things that would have to be studied and experimented with if northern natives were going to make a decent living without all of them going into jobs on the pipeline. Where the good timber is, how to log it and saw it, how to make it into houses and furniture and a lot of other things. How to use wood to produce cheap heat and power for houses and small manufacturing. How to travel in the country

to get at the fur and the meat. How to store the food and tan and manufacture the fur into valuable clothing. How to educate the kids in remote areas using radio and TV and video.

This is the kind of research a person would expect if the Government was serious when it stated its northern Development priorities. I looked over this list of 18 million dollars worth of research, 175 research projects costing $100,000 each on the average.

I found one project with a price tag of 100,000 dollars to collect data on the mortality of fish angled and released, and seismic survey effects. Mr. Commissioner, I did not see any item on the mortality of northern natives angled into pipeline employment and then released.

There was one $17,000 project to study the behaviour of insects in the northern environment. Mr. Commissioner, I could have answered that myself, Those that have jaws bite, and those that have stingers sting.

THE COMMISSIONER: How did the research turn out on that?

A There was a $50,000 study of problems of modernization among native people in the north. Every native in the north will tell you that the main problem of modernizaation, Mr. Commissioner, is the studies. For the past five years every family includes a mother, a father, the kids and a sociologist. They come in with the geese in

the spring and leave with the geese in the fall. They think that we are laboratory specimens. We in the Northwest Territories have made more PhD.s than the Canada Council.

There was one research project which cost $270,000 on the efficiency of explosives in cold weather. I thought this would be useful to the natives considering how useless all the rest were.

But I want to be more serious about this. It is a serious matter because our lives depend on it. I mean that in exactly the way I said it. I looked over the list of $18 million worth of research. I would like to find research into food, nutrition, housing, heating, clothing, medical care, better education, using fish and game and forest, off road transport, small industry, all these things that are so important if the native people are going to be able to secure a decent life.

There were 135 projects which cost $100,000 each on the average. I could not see a total of $100,000 which dealt with anythingthat had anything to do with the native people making a decent living in the Mackenzie. NOt the value of one project, out of the total of 175 projects , a little better than 1 1/2%. 1/2 of 1% of the research money spent on the government's first priorty 99 and 1/2 % were spent on the environment and mineral development, 99 and 1/2% spent on research to meet the objectives of the white society.

1/2 of 1% spent on research to meet the needs of northern native society. We need the knowledge and the technology so that we can get back closer to the land again, but not in the old primitive way. The Federal and Territorial Government promised us something like this and they gave us nothing like this. They will keep on promising, but until a lot of new and good research is done. A lot of experimentation and pilot projects are carreid out, they will not be able to deliver because they will not know how to do it. Neither will we.

So what does this mean? Let me tell you what it means. First, we will be kept hanging up with no economic life of our own from now until the pipeline starts. When the native rights and claims settlement is made, we do not know what to ask for because no one knows what kind of resources and technologies the native will need to make a decent living.

The government will force the pipeline builders to take the responsibility for all natives in the valley for four or five years. There will be 600 or 700 token natives on the pipeline. There will also be 10,000 new southerners in the valley. By the time the pipeline is finished, they will have the renewable resources all sewed up.

When the pipeline is done and the bottom falls out all we will have is a wrecked society.Worse than some of the settlements are experiencing it now.

THose natives that went all the way with the southern society will be O.K. They may not be doing what they want to be doing, but they will have some income and some status. The rest will be just like the worst Indian reserves we find in the south. This is the picture that I get from between the lines in this list of research projects. Does anyone want to show me where I am wrong? I will be listening and all the native people in the north will be listening.

What we need is some real research into natural resources. NOt how animals can be kept healthy, but how people can be kept healthy. How the native society can be kept healthy and can survive the invasion. What we need is some real research and some experimentation on housing, food, clothing, fuel, education, recreation, industry.. and all the rest. WE have to have new technologies and new production systems for using natural resources. The renewable natural resources. For the benefit of all of the native northern people.

The research has to be planned by the native and northern people and run by northern people. We do not have the expertise anymore than the Government has the expertise, but we can find it. And we can make it work so as to get the knowledge that we need. The Government cannot do this or it won't do it. THis list of Government research projects clearly proves that.

If we don't do this and get some honest help in doing it, we're going to be finished, we'll be dead as people, a lot of good men and women will be dead as individuals, because say what you want, it's going to be rough and that zoo up in Inuvik is going to look like a Sunday School by comparison.

As this book shows, the government spent $18 million on the biology and engineering in 1970 and '71. $9 million each for the government's two lowest priorities. Nickels and dimes for its highest priority. The Government of Canada obviously needs some help, or its Civil Servants are going to make a liar out of it.

We, the native people of the north, would be glad to help if the government would fund research and experimentation which we would design. But it's obvious that we can't deal with the Civil Servants on this. If they are clever enough to make a liar out of their own boss, the Privy Council of Canada, they are clever enough to complicate the procedures and obscure the issues, and delay action to the point where we are paralyzed.

In summary, Mr. Commissioner, I am prepared as a northerner to submit to you a proposal in detail for examination of the resource base of the Upper Mackenzie from the perspective of northern native needs, relating these to the many and various technological possibilities for more effective use of the resources in the interest of the native people and northern society as a whole.

Thank you.

THE COMMISSIONER: Thank you very much, Mr. Mercredi. Would you leave with the Commission the statement that you read so that it will form part of the official record of the Inquiry, and would you, when we adjourn, take up with Mr. Scott, Commission counsel, any further submission you wish to make along the lines that you indicated in the closing passage of your statement, and would you also show that book to Mr. Scott? I think we probably have it but it sounds as if it might be of usefulness to us.

(WITNESS ASIDE)

THE COMMISSIONER: So are we to adjourn then until nine o'clock tomorrow morning?

MR. SCOTT: Yes, Mr. Commissioner.

THE COMMISSIONER: We'll adjourn until nine tomorrow morning.

(SUBMISSION OF J.G. MERCREDI MARKED EXHIBIT 81)

(PROCEEDINGS ADJOURNED TO MARCH 20, 1975)

MACKENZIE VALLEY PIPELINE INQUIRY

IN THE MATTER OF AN APPLICATION BY CANADIAN ARCTIC GAS PIPELINE LIMITED FOR A RIGHT-OF-WAY THAT MIGHT BE GRANTED ACROSS CROWN LANDS WITHIN THE YUKON TERRITORY AND THE NORTHWEST TERRITORIES FOR THE PURPOSE OF THE PROPOSED MACKENZIE VALLEY PIPELINE

and

IN THE MATTER OF THE SOCIAL, ENVIRONMENTAL AND ECONOMIC IMPACT REGIONALLY OF THE CONSTRUCTION OPERATION AND SUBSEQUENT ABANDONMENT OF THE ABOVE PROPOSED PIPELINE

(Before the Honourable Mr. Justice Berger, Commissioner)

Yellowknife, N.W.T.
March 20, 1975.

PROCEEDINGS AT INQUIRY

VOLUME XXII

ALLWEST REPORTING LTD.,
4299 CANADA WAY,
BURNABY 2, B.C.

APPEARANCES:

Mr. Ian G. Scott, Q.C. Mr. Stephen T. Goudge, Mr. Alick Ryder and Mr. Ian Roland	for Mackenzie Valley Pipeline Enquiry;
Mr. Pierre Genest, Q.C. Mr. Jack Marshall, Mr. Darryl Carter, and Mr. John Steeves	for Canadian Arctic Gas Pipeline Limited;
Mr. Reginald Gibbs Q.C. Mr. Alan Hollingworth	for Foothills Pipelines Ltd.;
Mr. Russell Anthony, Prof. Alastair Lucas & Dr. Andrew Thompson	for Canadian Arctic Resources Committee;
Mr. Glen W. Bell and Mr. Gerry Sutton	for Northwest Territories Indian Brotherhood and Metis Association of the Northwest Territories;
Mr. John U. Bayly	for Inuit Tapirisat of Canada and the Committee for Original Peoples' Entitlement;
Mr. Ron Veale and Mr. Allan Luke	for Yukon Native Brotherhood;
Mr. Carson H. Templeton	for Environment Protection Board;
Mr. David Reesor	for Northwest Territories Association of Municipalities
Mr. Murray Sigler	Northwest Territories Chamber of Commerce

INDEX

Yellowknife, N.W.T.
March 20, 1975.

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

MR. GENEST: Mr. Commissioner, before Mr. Hollingsworth resumes his cross-examination, I have advised those of my friends who I've been able to speak to today that we have now received two early cross-delta reports we have available for inspection. The alignment sheets as to which I spoke to you were put on the same plane that Mr. Marshall was put on yesterday, they were confused with some band instruments, and I am informed they were put off the plane at Edmonton and we are hoping that they are going to arrive today, The trunks which contain these also contain the minutes of the meetings in April of 1973 requested by Mr. Anthony. Again I am hopeful that we are going to get that sorted out with the P.W.A. during the morning, and have them available this afternoon.

I apologize for this. They were checked as personal baggage of those who were coming up yesterday and once again we seem to be having problems. But I hope to have them this afternoon.

MR. SCOTT: Mr. Commissioner, I'm sure Mr. Genest as usual is doing the best he can. It need hardly be said that not only Commission counsel but each of the participants is concerned to have this material. We're three weeks into the hearing with a route change of very substantial

proportions that was announced just shortly before the hearing. We have yet received no documentation whatever with respect to it, and it's contemplated that we should just carry on as if things are the way they were four months ago. Now I know that Mr. Genest will do the best he can. I presume that we won't have any talk about the urgency of this matter from Arctic Gas when it's unable to provide the essential documents on which its route -- on which its recent route is based. Well, an end of that at least for the time being.

MR. GENEST: Well, I will bleed publicly for Mr. Scott's benefit.

MR. SCOTT: I'm sorry to see my friend bleed publicly. I hope he and his clients won't complain publicly as they have been doing from time to time in the media about urgency, because if they can't comply with the simple production of a route change in time for the Inquiry to deal with it, it seems to me that they'Re in no legitimate position to complain to the public that there is some urgency about this matter.

THE COMMISSIONER: Mr. Hollingsworth, I was hoping to have a chance to gavel this Inquiry to order this morning.

(LAUGHTER)

I should say I think all of you might be interested, this is an historical note that I have received a letter from Mr. Henry J. Mann of Chilliwack, B.C., who says:

"Dear Justice Berger:

I have read a news item in 'The Sun' which said you had to use an ashtray as a gavel during your hearings. Enclosed is a gavel which contains a small bit of the history of the Territories. It was made from a timber taken from the 'S.S. Mackenzie River' which travelled the Mackenzie River system for many years. The gavel was made by Mr. Joe Bird, carpenter foreman with the Government at Fort Smith. Mr. Bird's father was a long-time river pilot on the northern river system. I would be very pleased if you would accept the gavel as a gift. Incidentally, the'Mackenzie River' was a Hudson's Bay Company boat which carried much of the pipe for the Canol Pipeline. On one occasion she pushed 1,600 tons of pipe from Fort Smith toNorman Wells. In those days that was a very large load. As one who has spent many years in the north, latterly at Yellowknife, I would like to tender my good wishes for the successful conclusion of your difficult task.

Yours sincerely,

'HENRY J. MANN.'"

So I think I should tell all of you that I have accepted this gavel and I think, if nothing else, it should enable me to bring Mr. Genest and Mr. Scott to order oftener than I've been able to in the past.

I should say I've written to Mr. Mann and thanked him for this thoughtful and touching gift.

Well, Mr. Hollingsworth, we're ready for you.

MR. GENEST: Perhaps you'll need your gavel again, sir. There are two matters on which you requested information yesterday. One was the existence of 48-inch pipe in other locations. You recall you were asking Mr. Williams and he has that information, if it's convenient for him to give it now and my friend doesn't mind.

MR. WILLIAMS: Yes, our records indicate that in 1972 Interprovincial Pipeline constructed 80 miles of 48-inch pipe in Canada. This was installed in 16 loops between Kingman, Alberta, and Gretna, Manitoba. The pipe was API, 5 LX 52, with a wall thickness of .406 inches. In addition, in 1973 our records show that they installed 179 miles of 48-inch pipe, 143 miles was in Canada spread out in sections in Alberta, Saskatchewan and Manitoba, and 36 miles was installed in Minnesota.

THE COMMISSIONER: Was the wall thickness the same?

MR. WILLIAMS: To the best of my knowledge, sir, yes.

MR. HOLLINGSWORTH: There was another matter, Mr. Genest?

MR. GENEST: You requested the buoyancy, which we left when Mr. Mercerdi gave

evidence, I think that was the last question, and Dr. Hollingshead has got his slide rule out.

MR. HOLLINGSHEAD: It was a question of the relative buoyancy of the different pipe sizes. The 48-inch pipe is approximately 75% more buoyant than a 36-inch, and approximately 30% more buoyant than a 42-inch. This depends in no small measure on the relative wall thickness of the pipes involved.

MR. HOLLINGSWORTH: Thank you, Dr. Hollingshead.

JOHN IVOR CLARK
GARRY WOOD HOLLINGSHEAD
EDWARD CHARLES McROBERTS
WILLIAM ALEXANDER SLUSARCHUK
NORBERT REUBEN MORGENSTERN
RICHARD H. COOPER
R.M. HARDY
GUY LESLIE WILLIAMS, resumed:

CROSS-EXAMINATION BY MR. HOLLINGSWORTH (CONTINUED):

Dr. Clark, on page 11 of your printed notes, printed remarks, perhaps I might say, there is the statement that "unstable terrain is most common in high ice content permafrost areas, on sloping ground adjacent to rivers, near the ocean and in some parts of mountainous regions."

For the most part, where are the high ice content permafrost areas of the proposed route?

WITNESS CLARK

A Sorry, I did not hear the end of your sentence there.

Q I said, for the most part where are the high ice content permafrost areas of the proposed route?

A For the proposed route. In the continuous permafrost zone, sir.

Q In other words, in the north?

A Yes.

Q And the locations near the ocean, would they be exclusively along the coastal route?

A Yes.

Q And the parts of mountainous regions which are unstable, would they be exclusively on the interior route?

A Yes, sir.

Q And the sloping ground adjacent to rivers, I assume would prevail all along the route?

A Yes, sir.

Q Would sloping ground exist on the cross-delta route going in and out of the water?

A There are very low banks on the cross-delta route, sir.

Q And does that count as being near the ocean?

A Not in the sense that we use it. What is intended here when we say "near the ocean" is directly adjacent to it. There are areas of coastal retreat.

Q Shallow Bay is part of the ocean, is it not?

A No, Shallow Bay is part of the Delta, rather than retreating, that is actually building up. Agrading.

Q Areas near the ocean which are unstable, how near the ocean must they be to qualify --?

A It varies along the coast. I believe that there are some figures quoted for different regions along the coast as to how much coastal retreat has occurred over the time span that people have records, and I cannot lay my hands on those numbers -- or I could lay my hands on those numbers with time and I could produce something for you on that.

Q To the best of your recollection you could not tell me how near the ocean instability would possibly occur?

A It would be right adjacent to it.

Q Within --

A Within feet or hundreds of feet.

Q And on page four of your notes, the last paragraph thereof, it states, "Along the rest of the pipeline route ...", and that means excluding river crossings from what I interpret earlier, "...about 95% of the terrain is flat to gentling undulating with slopes less than 3°." You did mean 95% of the terrain apart from river crossings in that statement, did you?

A That would include river crossings, sir, slopes.

Q Well, perhaps we could read -- perhaps you could read the whole paragraph, sir.

A Yes.

"Major ice jams can occur during spring break up resulting in a temporary increase in upstream water level and possible river bed scour. These aspects of river crossings have been considered for each major crossing."

Now, on my own note here I have marked and it did not come out that way, that there is a new paragraph there.

"Many of the steeper slopes along the pipeline route are located at the approaches to river crossings. Along the rest of the pipeline route about 95% of the terrain is flat to gently undulating with slopes less than 3°."

Q Stopping there then Dr. Clark, I would interpret that to mean that from apart from the area of river crossings that 95% of the remaining route --

A I could see how you --

Q -- on slopes less than 3° --

A I can see how you could interpret it that way in --

Q And you are saying that that is not the intention of the paragraph?

A Tha is right and in our report on slope stability here, we have a catalogue of all slopes and Dr. Morgenstern showed the 686 slopes, I believe, that are over 3° in inclination and that would include the river crossings.

THE COMMISSIONER: WEll that sentence, just so I understand you, that sentence should really say "along the whole of the pipeline route, about 95% of the terrain is flat to gently undulating with slopes less than 3°?

A Yes, sir, and that is my understanding from the analysis that was made of the slope angles.

Q Now, of the 600 and some odd slopes which Dr. Morgenstern listed, are you able totell me how many are on the interior route?

A This is the prime route that we are talking about,sir.

Q By prime route you mean coming along the coast / and down the Mackenzie VAlley ?

A That is right, sir --

Q Or do you mean going across the delta?

A Along the coast, down the Mackenzie Valley and the route as filed originally. We have not had time to reassess the east of Simpson. I do not believe that the numbers will change a great deal.

Q Supposing that we left off the coastal route for the moment and substituted the interior route. What would that 95% figure, -- I am getting ahead of myself -- I assume that that 95% figure would be reduced.

A The overall percentage would probably reduce. We don't think it would reduce a great deal because of the fact that this incorporates all the rest of the route from the junction down.

Q Well sir, the interior route, looking at it with my naked eye through these glaring lights, would appear to be -- the part in Canada would appear to constitute about 20% of the route, is that not so?

A The part in Canada constituting 20%?

Q The part of the interior route in Canada would appear to constitute about 20% of the total route.

A Perhaps; I would have to --

Q I'm not trying to pin you down to an absolute.

A It is quite an easy percentage to work out, simply by looking at the scale of the map and taking the miles and dividing it by the total.

Q And does not that route come down from mountains in Alaska and go up over the Richardson Mountains in order to come down through the Mackenzie?

A It comes through the mountains, yes.

Q And does it not encounter slopes of greater than 3 degrees in slope?

A Oh, indeed it does encounter slopes greater than 3 degrees.

Q And does it not encounter more slopes than the coastal route does, greater than 3 degrees?

A Yes, it would encounter more, yes.

Q But you still say that the percentage as expressed in this paragraph that's been read would read approximately the same or a bit less?

A No sir, I said it would change but not a great deal.

Q Well, how much would it change, sir?

A That would require an analysis and it's something that we could do.

Q Well then, if I can go back to the unstable terrain which we discussed a bit earlier and the terrain which is on slopes greater than 3 degrees, it's a fair statem ent to say that this -- these constitute one of your most difficult problems in the geotechnical sense, is that not right?

A I'm not following your question, sir, so I understand it.

Q The problems which we have discussed this morning, the area near oceans, the area coming down to river banks, the area of high ice content and the slopes of greater than three

degrees, these would constitute your major geophysical problems, would they not?

A Those would be the areas of our major geotechnical concerns, yes.

Q I'm sorry, geotechnical, and these areas are by and large on the coastal route coming to the Mackenzie Delta from Alaska or on the interior route coming from Alaska to the Mackenzie Valley, is that not the case?

A Any concerns associated with the ocean would have to be along the coast. The pipeline is, however, well back from the coast so that it does in fact get what we would call terribly near to the ocean to the point where it would be affected by coastal retreat. This is a general statement on unstable terrain. Now with respect to the slopes, our routing that has been selected on the basis of our analysis does not cross any slopes which currently show signs of instability.

Q But you recognize that these are areas --

A Yes, we have arbitrarily accepted three degrees as being a point beyond which we would make some check of every slope.

Q And if you didn't have slopes of three degrees or greater, you'd be happier, would you not?

A I would say that from every point of view if we had thousands of miles of

flat ground that at least people building the pipeline would be happier, yes.

Q Would I be correct in my assumption that there is such a thing as a geotechnically sensitive area?

A Yes, you would be.

Q Such as the areas we've described, for instance?

A It's usually expressed as terrain sensitivity.

Q Can you expand on that, please?

A Well, terrain sensitivity -- there are several factors that go into assessing sensitive terrain, and terrain for instance that might be sensitive this year, might not be sensitive next year. It also relates to the depth of thaw in the active layer, the climate, the amount of rainfall, such things as forest fires and so on; but normally the sensitive terrain is terrain with a very high ice content.

Q Is unstable terrain geotechnically sensitive by your definition?

A By our definition, unstable terrain is where an instability exists, where there is movement occurring.

Q I'm sorry, is the answer to my question "yes" or "no"?

A Unstable terrain, by our definition, is terrain that is failing, it's unstable.

Q And is that considered geotechnically sensitive?

A Yes, it would be.

Q Would you refer to Exhibit 66, sir? I'm sorry, that's the exhibits in support of the amendment at Fort Simpson, and on page 16 of the environmental statement, sir, I would refer you to a passage, the last sentence particularly, sir, states:

> "Along the east Fort Simpson routing, the Ebbutt and Red Knife Hills are noted as being particularly sensitive to disturbance, thus requiring special erosion control measures."

You'll agree that's what that says, sir?

A That's right.

Q And further back in the same volume in the route alignments, the map I found which seems most helpful -- there is no page, it's in the section called "Construction Plan", and the drawing number is 1-B-0231-1006. That shows, among other things, the Ebbutt Hills, does it not, sir?

A Yes, it does, sir.

Q And it shows the pipeline going straight across the top and down the side of the other hill, is that not right?

A Yes sir.

Q And in fact it shows the countryside, according to height, by the lines on it,

does it not, sir?

A Yes sir.

Q And to the south -- that is to say between the Ebbutt Hills and the river -- can you describe the lie of the land there?

A In the Ebbutt Hills and the river, it is generally flat land there.

Q And it is not swampy?

A It is not shown as swampy on this plan and --

Q The swampland is shown further over to the west --

A The swampland is shown there, yes. I am not sure if that is a feature of the terrain, however, or a feature of the land --

Q Are there any geotechnically sensitive areas between the Ebbutt Hills and the river, sir?

A I cannot answer that, sir, from this map.

Q Do you know it on the basis of your knowledge?

A No, sir.

Q Does anyone on the panel?

A There is no slope problems that we know of there, I can tell that from the map.

Q Maybe I can ask it this way: As between the area which has been described as sensitive, the Ebbutt Hills, as compared to the land between the Ebbutt Hills and the Mackenzie River, which would be less sensitive geotechnically?

A You are asking me to

compare the route -- the land which the route now crosses compared to the land between the route and the river.

Q I am. There is no evidence of sensitivity between the river and the Ebbutt Hills, is there, sir?

A Well, unfortunately, sir, this is not a sensitivity map and I cannot interpret it in that context. I could undertake to perhaps look at the types of maps that might give us more information than this one.

Q But you are aware of no sensitivity problems between the Ebbutt Hills and the area, are you?

A I am not aware of any problems between the Ebbutt Hills and the river.

Q But you are aware of some in the Ebbutt Hills because your statement says that.

A Within that total area of the Ebbutt Hills there are potential problem areas and existing slides in some locations.

Q Do you know of any geotechnical reason why the route could not have gone around the Ebbutt Hills to the south?

A No, it would not be selected on the basis of geotechnical reasons. There is no reason why it could not go south and I could see no reason why it could not go north or where it is.

Q Strictly within the field of your expertise you see no reason why that route change could not be made?

A That is right.

Q The geotechnical personnel did help on the location of this route, did it not?

A Yes, to the best of my knowledge.

Q And did they assist on the Fort Simpson amendment?

A Geotechnical personnel to the best of my knowledge, yes.

Q Are you aware of any particular event that is occurring around the Ebbutt Hills, sir?

A I beg your pardon?

Q Are you aware of any particular event of man that is occurring around the Ebbutt Hills in the near future?

A Any particular event around the Ebbutt Hills?

Q Yes.

A Well, we propose to be doing some --

MR. GENEST: You mean the Caribou Carnival? I do not understand the question.

MR. HOLLINGSWORTH:

Q Are you aware of any scientific studies going on around the Ebbutt Hills?

A Any seismic studies?

Q Scientific studies.

A We have ourselves land use permits to do drilling in the Ebbutt Hills.

Q Are you aware that the top of the Ebbutt Hills has been designated for the International Biological Program?

A That is not my field of expertise, but I am sure that our biologists, if that is the case, would probably know of it, but that is not known to me.

Q Was anyone else on the panel aware of this? Do you know anything about the International Biological Program?

A I know it by name.

Q Is that all?

A That is about all, yes.

WITNESS WILLIAMS:

A The International Biological Program is referred to in several locations in the response to the Assessment group inquiry. I think it is question number -- I think it is in question number 7. I would have to check that for sure.

Q But notwithstanding this study the route is neverthe less projected to go straight across the top of the Ebbutt Hills rather than around it?

A I thought the question was, were we aware of the work of the International

Biological Program.

Q I had asked that, sir, yes. --And your answer to that question is what?

A It was that we are aware of it and we have referred to it in response to the Assessment Group questions, but not specifically with respect to Ebbutt Hills.

Q And my next question was notwithstanding that knowledge of yours, the prime route is still intended to go straight across the top of the Ebbutt Hills and not around it?

A That is what we have filed in the amendment, yes.

MR. HOLLINGSWORTH: Thank you. I do not think that I have any more questions, Mr. Commissioner.

MR. ANTHONY: Mr. Commissioner and panel, we have been rather silent through the exchange between Mr. Scott and Mr. Genest about the technical nature of the evidence -- although we of course have very serious concerns about the technical evidence and as may become evident as we go through some of the questions that I have for the panel, I would hope that you would attempt to treat me, as in fact I am, a layman on this -- on these points and will bear with me as I attempt to simplify some of these concepts so that I can understand them and I invite you to just answer these questions and call a spade a shovel if you have to -- as a matter of fact I attempted to get some questions for Dr. McRoberts

who did not have his own slide show and I may have some questions to direct to you in any event.

CROSS-EXAMINATION BY MR. ANTHONY:

Q I was wondering if we could start perhaps by looking at the Pointed Mountain line which we just referred to very briefly to see what we can learn from it and I direct this perhaps to you, Dr. Clark, initially. My understanding is that that line was constructed almost entirely in discontinuous permafrost, is that correct?

WITNESS CLARK:

A Sir, I have never myself looked at the line, but my understanding is that it passed through small patches of permafrost. -- which would be discontinuous, yes.

Q Right, and then I am accurate too, am I not that the line was not a chilled line?

A That is correct, yes.

Q We have had evidence over the last number of days about the general problems that you'll be experiencing and the tests you've done for frost bulbs, and what it does and questions, for example, of differential heave, which would be directed, I anticipate, towards the question of the integrity and stability of the pipeline. Is that accurate?

A Yes sir.

Q Now would I be right and would you agree with me that one of the important geotechnical problems is in fact this shift or the interfacing between frozen and unfrozen terrain?

A We consider it an important consideration, yes.

Q And when you're talking in terms of differential heave, this is really where it becomes crucial, where some parts heave at different rates than others, and there is interaction, is that correct?

A Yes, as I tried to explain, sir, it's the rate of change of curvature that is of concern to us. I think that is clear.

Q Now if we may then generalize from this concern of the interaction of the interface between the frozen and the unfrozen, or in some cases two different rates of freezing, you would then experience the same sort of problem of interaction when you go through areas, for example, of discontinuous permafrost, is that correct?

A Yes sir.

Q So that when you have a pipeline going through areas where it goes through unfrozen and then through unfrozen, this is the same geotechnical problem of the interface.

A Yes sir.

Q And in fact when you're in areas of continuous permafrost, you still have the same geotechnical problem of this interface because of what are known as fens.

A In the continuous permafrost?

Q Yes.

A There are areas of unfrozen ground in the discontinuous permafrost.

Q Sorry, there are areas of unfrozen ground in the continuous --

A In the continuous permafrost, yes.

Q And so we have in the discontinuous permafrost the situation of basically unfrozen terrain with patches of frozen, and in the continuous permafrost, a permafrost of frozen terrain with patches of unfrozen terrain.

A Yes, and there is a transition from no permafrost to scattered permafrost to widespread permafrost.

Q This would be the type that you'd experience along the totality of the route.

A Yes sir.

Q And the interface problem of the rapid shift from frozen to unfrozen would be characterized, for example, when you go along your route and run into a fen, for example.

A If it was unfrozen, yes.

Q Now am I accurate in describing this problem of patches of ice in discontinuous permafrost and fens in continuous permafrost as rather typical terrain for the proposed route of the pipeline?

A Yes.

Q In fact, these problems will be encountered more or less regularly from say Arctic Red River south, in any event?

A Yes sir.

Q And the question of the fens, of course, would be encountered almost along the entirety of the route in the continuous permafrost.

A Yes, Dr. Slusarchuk pointed out to me quite correctly that in the continuous permafrost zone we skirt around most fens. The unfrozen ground that would be encountered in the continuous permafrost would be largely at water bodies.

Q Well then, you've got me here. I understood that in fact you don't know the location of fens until you've done some more detailed land study, is that not accurate?

A I don't think that's

accurate, no.

Q Well, so I understand your evidence, you know the location of all fens along your proposed pipeline route?

A We have the terrain analysis, as Dr. Mollard described last week.

Q Yes, we had that before us, but I'm wondering if it's your evidence to us now that along the proposed pipeline route you do not intend to cut across any fens.

A No, I don't believe that's a fair statement, I couldn't say that without examining and seeing where we do.

Q So in any event you will be -- you anticipate then, since this is a common terrain feature, that you will be encountering this problem in the permafrost area.

A I would expect to some small scale.

Q Certainly. Now if I may again oversimplify, would I be accurate in saying that perhaps the geotechnical policy with respect to Pointed Mountain was that they will go unchilled through patches of permafrost, having come to the conclusion it's better that they will melt the permafrost in those areas where they encounter it.

A I couldn't speak to the policy, sir.

Q But that will be the effect, will it not, of an unchilled pipeline going

through permafrost?

A It would melt the permafrost, yes.

Q And I would be accurate, too, in saying that the geotechnical policy, if I could use that phrase again, with respect to this line is in fact the opposite.

A We do have parts of the line going through frozen ground where the gas would not be chilled, after the last point of chilling; less continuous permafrost reaches down into Alberta.

Q All right, let's deal now with the area north of 60, and I understand that that portion is to be chilled throughout, is that correct?

A Yes sir.

Q And in that portion particularly areas, for example, of Arctic Red River south, you'll be going through what is known as discontinuous permafrost.

A Yes sir.

Q So you in fact will be having a chilled pipeline going through discontinuous permafrost areas.

A That's right.

Q And in those discontinuous permafrost areas you in fact have determined as a policy that you would rather go through the unfrozen territory with the frozen line than the opposite way

around.

A Yes sir.

Q Now would I be accurate in saying also that when all this is said and done on this question of the problem of a chilled pipeline, that your key geotechnical consideration has been to ensure that there's no permafrost degradation.

A That has not been the key consideration, no.

Q Well, as I imagine that there are problems encountered if you go with an unchilled pipeline through permafrost, as you outlined, and as has been outlined in the last three days in evidence there certainly are problems if you go with a chilled pipeline through unfrozen territory.

A Yes sir.

Q Now by making the decision that you would rather have the chilled pipeline run through unfrozen territory, are you not making that decision on the basis that you do not want to melt permafrost? Isn't that what it comes down to, and the reason for a chilled pipeline?

A Yes, that's a reason, yes sir.

Q In fact, am I not correct that the test facilities that we heard about, that were constructed in Northern Canada were designed in fact to study this problem of permafrost degradation or the effect of a chilled pipeline on permafrost?

A That was one of the intents, yes.

Q As a matter of fact, the original model that you referred to, the computer models which I believe is the Esso model for purposes of identification, was in fact the model based on a hot oil pipeline, the purpose for the initial investigation was to understand the problems of permafrost degradation.

A Not the original model, sir. I believe the original model used by this project was one developed by Arctic Gas; the Esso model to which you refer was licenced for use after the test-sites had been operating for some time.

Q They were designed basically to test or to verify or to evaluate your results as it relates to this problem of permafrost.

A I'm not sure that I understand it correctly, but I think the answer is "yes", the way you -

Q It's the answer I want, so I'll stop. Now, perhaps we can then go to the question of the Russian line, if I can put it that way, the information you have on that and I have my friend, Mr. Genest's advice that there will be a report coming forward and we may hae an opportunity of examining this in more detail, on the assumption we're not being foretold of another amendment to the proposal, there is no test lateral amendment, is there, Mr. Genest?

MR. GENEST: Not that I am aware of.

MR. ANTHONY: Well then perhaps I can merely deal with it in a very general way then, and again I direct it to either you or Dr. Hardy.

Q Can you tell me whether that was in continuous or discontinuous permafrost, the part that you know of?

A I can't, sir, I'll defer that to one of my colleagues who has been there.

WITNESS HARDY: Well, the section of pipeline that I saw, sir, around Yakutskt was in continuous permafrost.

Q Continuous?

A Continuous permafrost, but there was quite a thick active layer, and the conditions are really not comparable. On their lines further north and west, then I'm not sure what the situation would be. I would expect, though, that they would be in continuous permafrost, from the geographic location.

Q Well, without getting into too much detail on it, the other point that you mentioned was that part of the line was buried below the surface and part was above. Now do you know whether that was part of the design, or is that just the way it ended up?

WITNESS CLARK: A I believe Dr. Morgenstern sir, was the one that mentioned that.

WITNESS MORGENSTERN: I assume

it was designed, but I can't give you any guidance as to criteria that in fact influenced where it emerged out of the ground.

Q Well, perhaps --

A Let me add it may have been a function of construction capability. I think they lack some of our heavy equipment and that may also influence design for the subsequent facility as it appears. They, I think, our large ditching capability doesn't exist in their pipeline practice.

Q I gather from the application and from the evidence that we've heard over the last few days that the bulk of your testing with respect to permafrost conditions was done at the Sans Sault test facilities, is that correct?

WITNESS CLARK: No sir. That's not correct.

Q You had also test facilities at Fort Norman and Prudhoe Bay, is that correct?

A There were test facilities at Norman Wells and at Prudhoe Bay, but I assume that you mean,the bulk of our testing,that you're including the entire spectrum.

Q Now, sir, I meant basically your field testing or your test site experimentation.

A Oh, yes, the Sans Sault Test Site was the largest of the three.

Q And that of course is located in permafrost terrain?

A Yes, sir.

Q And in the lines that we saw on the slides of the Sans Sault did you have any test lines through a fen area?

WITNESS WILLIAMS:

A Not in the active sections we showed on Monday, no. It was in -- all of the buried sections were in permafrost.

Q So this typical terrain problem that we have discussed earlier of the rapid transition from frozen to unfrozen, was not in fact tested as such in the test facilites that you operate?

A That is correct with respect to Sans Sault, yes.

Q Well, did you do experiments on the rapid transition, for example, putting a line through a fen in any of the other test facilities?

A My recollection is that the Prudhoe Bay Test facility did run through a small pond, one corner of the circuit at Prudhoe Bay

ran through a water area --

Q But that is really not the same problem that we have been discussing, is it?

A I think you are correct.

Q Thank you.

Now, I understand that at least if the map is still accurate, the route is going along the east side of the Mackenzie, but your Sans Sault Test facility is on the west side of the Mackenzie and I understand in your evidence the reason for this was that this was representative terrain, is that accurate? In why you located where you did?

A We located it there -- I think I pointed out first for several reasons -- but, yes, one of them was that it is representative of the terrain in the Mackenzie Valley.

WITNESS HARDY:

A It represented severe conditions too.

Q Sorry, pardon me, Dr. Hardy?

A It represented severe conditions at Sans Sault Rapids.

Q Well, we dealt with the question of fens, but am I not accurate, Mr. Williams, that in fact the Sans Sault Test Facility is what is known in geomorphic terms as a river terrace?

WITNESS WILLIAMS:

A Yes, I think that Dr. Mollard classifies it as "HT", High Terrace.

Q "HT" or river terrace, if I may use that phraseology, of course would be the underlying control landform. Now, my understanding of that, this affects things like drainage patterns, depth of the active layer, vegetation that will grow on it and so on. Now, could you tell me what percentage of the pipeline route is on river terrace?

A No, I do not have that number.

Q Can anyone help you?

WITNESS CLARK:

A I do not believe that anyone could help you with that, sir. But that is something that could be picked off from the alignment sheets.

Q Well, I am wondering if my friend would undertake to provide you with that information --

MR. GENEST: Am I so directed by the Commissioner?

THE COMMISSIONER: Yes, I think we should know that.

MR. ANTHONY:

Q But you would agree until the accurate figure is known -- would you not agree with me that in fact it is representative of a very small percentage of the Mackenzie Valley terrain?

WITNESS WILLIAMS:

A I would agree that probably the amount of route in "HT" is very low, but I would not agree that the soil and ice and permafrost conditions at Sans Sault are not representative of the terrain along the Mackenzie Valley.

Q But does not the fact that it is on a river terrace affect all of these elements?

A Is it not -- it seems to me that it is also true that the bench on the east side of the river between the Mackenzie and the Franklin Mountains could in general be described as a river terrace.

Q Well, I will leave that argument to a later date, perhaps when we have this information as to what percentage of the route is in fact river terrace.

MR. SCOTT: Mr. Commissioner, our people have done an analysis and we will be calling evidence, if it helps my friend, of that which reveals that substantially less than 1% is of the terrain typing that Dr. Mollard has identified is found at Sans Sault.

MR. GENEST: I did not hear that, Mr. Scott.

MR. SCOTT: Substantially less than 1%.

THE COMMISSIONER: Substantially less than 1% of the route of the pipeline is

classifiable as river terrace or high terrace?

MR. SCOTT: Is classifiable as the Sans Sault location has been classified. The Sans Sault locaiton in terms of Dr. Mollard's terrain typing, represents substantially less than 1% of the terrain of the proposed pipeline. Now, that is our figure and we will have to prove it, but --

THE COMMISSIONER: Well, thank you for -- you would be even more interested in getting that information now, Mr. Genest than you were.

MR. ANTHONY: While we are on the question then of test facilities, perhaps I could go to Dr. Slusarchuk.

Q Could you tell me when the Calgary Test Facility was established?

WITNESS SLUSARCHUK:

A It started operating March 20, 1974, sir.

Q March 20, 1974.

A That is correct, sir.

Q And from your evidence I gather that the question of frost heave was perhaps the prime reason for the establishment of the Calgary test facility?

A Yes, sir.

Q And could you tell me where you studied the problems of frost heave before the operations at the Calgary Test Facilities got into

full swing?

A My self , personally, sir, or the project?

Q Well, we will start with you and then generalize it.

A Well, I did some work on both my Masters and my PhD work on Frost heave and I was associated with work at National REsearch Council -- that was involved with frost heaving.

Q I am sorry, I was dealing with test facilities, actual field testing of frost heave -- I mean did you operate -- was their field testing of frost heave at the Sans Sault Facility for example?

WITNESS HARDY:

A I think perhaps I could answer that better than anybody else;having the longest period of association and association in the early days. From my first association with the pipelines up in the Mackenzie Valley, I always realized that there was a problem of frost heave and we, in the first instance of location, it was not a governing problem, but far ahead, more than a year prior to the establishment of the test facility in Calgary, we had discussed that there needed to be some experimental work done for the whole problem of frost heaving and the question of differential heaving under the situations that you have been describing here this morning, it needed some study, see, and so it was not just an afterthought, it was always understood

that it had to be given special attention, but it was not necessarily a governing factor in the original location. It is a detail problem that you have to be able to handle and it could be that after you have selected a prime route, you would make some minor changes in the light of differential frost heaving concepts, but it was a thing that came on in the program and I personally had an assignment from N.E.S., just at about the time of the merger of the two groups, to do a basic study, as a sort of a state of the art study, as to where we stood at that time with the problem of frost heaving and out of that grew the test program, after a lot of other people had picked this up and studied it and there had been rather exhaustive discussions and finally it was put to the clients with an estimate of cost and finally the program was sanctioned and it went ahead, but it was not an afterthought in any sense of the word, sir.

Q If I may catch on to one sentence out of that, would I be accurate though in saying that the problems of frost heave, as they were understood, were not considered such a crucial nature that they had to be resolved or studied by field study before the actual route was selected --

A In my judgment they were not in that category. There are other considerations or that they could be considered as a special, very important problem and that is the way that they were dealt with. Certainly in the early stages,

that was my own judgment.

Q Now, if -- I come back to Dr. Slusarchuk, then -- this was set up in March of 1974 -- I gather from the fact that we received a report rather recently that your results are only starting to come out of that test facility?

WITNESS SLUSARCHUK:

A I mentioned, sir, that the field test facility started on March the 20th 1974. The program was actually initiated almost a year previous to that and it took us that length of time to get it into gear.

Q I was again referring to the question of the actual field testing of these problems that were identified in a general way through experience.

A That is right, we have been obtaining information from the field test site of course ever since we've started and that has been going on in conjuction with our laboratory studies both of our four-inch diameter tests and the model box and along with our engineering studies. Now, we have not gotten around to putting out a final report until just very recently, or an interim report on the results, that is correct, but we have had these results all along and we have been dealing with them on a daily basis of course.

Q Now, I gather that your point behind the -- your sand box study -- or is it model box -- was that the question of water in

deciding on frost heave, or the amount of water that is available is a prime parameter in determining the extent of frost heave and frost bulb formation.

A Water is certainly a necessary ingredient for frost-heaving, that is correct.

Q Now would you tell me the level of the water table at your Calgary test facility?

A Somewheres around six feet beneath the ground surface. It varies with the season, but six to seven feet, or something like that, as I recall it.

Q Could you tell me what the water table is along most of the prime route that you've selected for the Mackenzie Valley Pipeline?

A Could I tell you that?

Q Do you know that?

A It varies throughout the year, of course, and in some areas water that's ponded is at the surface, quite clearly. Other areas, on some slopes it's at some lower depth.

Q Well, perhaps just to get at the point then, could you indicate what percentage,in general terms, of the prime route or the alternate route, in fact, where the water table is six or seven feet or less?

A The water table is six or seven feet beneath the ground surface, or less? Do you mean higher up towards the ground surface?

Q No, as I - - well, I'll put it this way, the question of frost bulb

depends on the amount of water. Now your water table in Calgary was, you say, six foot, and down. I'm saying now could you tell me which percentage or what portion of the route is the water at six foot or lower? Similar to the Calgary test facility.

A No sir, I can't tell you that percentage. I'd like to say, though, that the availability of the water table is an important consideration when you start to have the depth of the water table being beneath the bottom of the pipe. The water that is in the water table above the bottom of the pipe and around the upper portions of the frost bulb is not necessarily contributing that much to promoting the rate of heave, It does change the effect of stress, of course.

Q Well --

A On the soil particles themselves.

Q -- without getting too technical, I wonder if my friend would similarly give us an indication -- I don't know whether my friend Mr. Scott has calculated this figure -- but what percentage of the route has a water table at the same level, i.e. 6 feet, as the Calgary test facilities?

A I suggest it would be along -- I just can't give you that number just now, sir, I just don't know.

MR. ANTHONY: Perhaps my friend would undertake to similarly provide that information.

MR. GENEST: I'd like to know about whether again this is something that can physically be done. Can the panel help me on that?

WITNESS CLARK: That would require extensive drilling operations for that period of time that you did that, sir. Water table is a dynamic thing.

WITNESS SLUSARCHUK: I'd like to make this point, Mr. Anthony, is that the position of the water table, we realize along the right of the way that when we bury the pipe the water table is probably going to be at least at that level, and therefore is not going to -- whether it's higher than that doesn't necessarily help out or restrict the availability to freezing fronts beneath the frost -- beneath the bulb.

MR. ANTHONY: Q Well, even as I understood C over V over the last while, that if in fact you're burying, putting the pipe through terrain that is in fact below the water table, you have different parameters, different factors acting on stability and other questions than if you bury it above the water table. Now, is that not correct?

WITNESS SLUSARCHUK: A Sir, we determine the rate of heat characteristics of a sample along the route, and our governing parameter there, as I presented in my slide show the other day, was the load on the frost front, and that changes with the position of the water table. The example that I gave you, to demonstrate the amount of frost heave

was with the water table at the ground surface. In other words, the worst condition.

Q That was in your model box test.

A No sir, that was the final example that I gave you at the end of the study to show you how we predicted, how we would predict the rate of heave along the pipeline route.

Q Well, I didn't really want to get into a technical argument, because I don't have that information handy. I may eventually want to get into that argument with you but for the time being I merely would like to know how much of the route has the same water table characteristics as the characteristics you used in your Calgary test facility? Now you say you don't have that and I just merely asked if that information can be available?

WITNESS HARDY: Mr. Anthony, I think when you use the term "the same characteristics" then it's a different ball park altogether, and we have the same characteristics in the test site at Calgary as on hundreds of miles on the pipeline. I'm afraid there's a misunderstanding, you see, in the concept you're presenting to us here, that the crucial thing in the design of this test section was, "Where is the water table?"

Now we know that the water table has -- is an important parameter and the test section was designed and location selected not to be representative of specific conditions on a mile

per mile basis along the pipeline, but as being representative of general conditions that are condusive to frost heave, and he had a water table within the height of capillary rise of the frost line and we had a water table above the frost line, and those conditions are the essential things that he had to be sure he had as matching the conditions that are condusive to frost-heaving on the pipeline.

Q Well, Dr. Hardy, I agree with you that there are a lot of considerations. I am merely trying to isolate one simple condition because I'm trying to maintain this on a simple basis, and perhaps I'm over-simplifying, but it seems to me that if you have a test facility with a water table at a certain level, and that level does not repeat itself anywhere else along the route, it tells you something about the sort of generalizations you can make. Now --

WITNESS MORGENSTERN: If I might interject, Dr. Slusarchuk went to great pains to demonstrate that water was freely available to the freezing front, and that represents the worst condition that such a facility could get at or could represent. In fact, in the selection of that facility, this was a prime consideration to ensure that water was freely available to the freezing front.

Q. Do I understand it then, what you're saying is that it doesn't really matter if the water table was lower there than you would

experience in the Mackenzie?

A It doesn't matter in the sense of establishing the design methodology to combat or to analyze for frost heave, yes.

MR. ANTHONY: Well, maybe that will be taken up, too.

Mr. Commissioner, I'm going to move onto another line. Would it be convenient to my friends to break now or would you like me to continue?

THE COMMISSIONER: What would you say, Mr. Scott?

MR. SCOTT: We're early, Mr. Commissioner, but I have no feelings about it one way or the other.

THE COMMISSIONER: Well, do you mind carrying on, say to 10:30, Mr. Anthony?

MR. ANTHONY: Q O.K., let us discuss then the question of a frost bulb, and again I'm going to try to simply, but if I'm simplifying so it's inaccurate, I'm sure you will catch me up on it. Now what we're talking about here when we're talking about the frost bulb is in fact the frozen area around the pipe.

WITNESS SLUSARCHUK: A Yes sir, that's correct.

Q Would you tell me what are the ideal conditions for the creation of a frost bulb? If I gave you the job of creating the biggest and best frost bulb you could, what sort of conditions

with respect to water, soil, etc. would you require?

A I'd ask for a very cold pipe and a rock without any water in it.

Q Sorry?

A I'd ask for a very cold pipe and a soil that would have no water in it, such as rock, and that would give me my largest frost bulb, or the largest position of the 32 degree isotherm around the bulb -- around the pipe, excuse me.

Q How would you classify what we call silty soil? Is it good for frost bulb building, or poor?

A For frost-bulb building, I'm afraid, sir, you simplified it so that I'm not sure what you're driving at.

Q Well, just taking I imagine the different soil conditions effect the extent of frost bulbs, is that accurate?

A Well, a silty soil is known to be a soil that is frost-susceptible, and it is also known that smaller -- small amounts of overburden pressure dramatically or significantly change the amount of frost heave. Now if absolutely no water was drawn into the frost bulb, for example we'll assume one temperature of the pipe, we would be predicting like what would be the most rapid growth of frost bulb that you could have. If in fact some water starts to migrate into the frost bulb, silty soil that's freezing,you would have to account for all that

latent heat that was brought in there, the water would come in and upon freezing, 144 B.T.U.s per pound and so on, you have to account for that and that would naturally slow down the rate of movement of the frost front.

Q . But am I right in saying, just again as a general statement, that in fact the silty soil is a frost-susceptible soil?

A A silty soil is a frost susceptible soil, it's traditionally known to be so, but it also has the very good characteristics from our point of view that it has a low shut-off pressure.

Q O.K., I'm really trying to find out the conditions than the remedial measures that can overcome that.

WITNESS HARDY: The misunderstanding here is between definition of frost-susceptible soil and size of frost bulb. Your questions were first directed at the size of the frost bulb, and that is the question Dr. Slusarchuk is trying to answer. When you bring in the phrase "susceptibility to frost action", that's got nothing whatever to do, primarily, with the size of the frost bulb. When you say a silt is highly susceptible to frost action, what is being said is that if you create conditions that are condusive to high segregation you will get more ice segregation, all other things being equal, with the silt than you will with some other types of soil. But that's got nothing whatever to do with the size of the frost bulb, the location of the 32 degree isotherm.

WITNESS MORGENSTERN: I think if I could also take up the question of what has been regarded as frost susceptible soils, the procedure in the past has been to classify these things on the basis of grain size, and your suggestion that silt or Dr. Slusarchuk's comment about silt is considered a frost-susceptible soil isn't observation on that basis, but the traditional classification ignored the effect of increasing load on the behaviour of soil, and it is the contribution here that Dr. Slusarchuk presented the other day that says in order to evaluate frost-susceptibility of the soil, we must also inspect its response to increased load on it.

Q Yes, well I appreciated that and I in fact tried to isolate merely the soil condition, ignoring the fact that if you surcharge it, some soils react better to surcharge, have a lower shut-off pressure than others.

A Yes, but the evaluation of frost-susceptibility should embrace that behaviour too.

Q Well, that's perhaps then the applied part of it, in other words when you're considering, if you use the model box, you could probably plot certain soils that are more frost-susceptible, or indicated to be more frost-susceptible than others, ignoring the whole question of surcharging which is really a measure to be applied with.

WITNESS MORGENSTERN: The traditional tests to evaluate frost susceptibility do not involve a surcharge. They're modelling the condition of a roadway in which the pressures on the soil are very small; in that sense they have been misleading or they have been exaggerating the potential of certain soils for frost-susceptible behaviour.

Q Can you give me an indication, though -- am I accurate, Dr. Slusarchuk, in just in a general sense, that a frost bulb under appropriate conditions would in fact expand over time, is that what I understood from some of your graphs?

WITNESS SLUSARCHUK: Yes sir.

Q Now do you recall from your -- I apologize FOR NOT asking you when you first set out before and I meant to talk to you earlier -- could you tell me the radius or the area the frost bulb created at your Calgary test facilities after the first five years?

A Now after the first five years?

Q Yes, I mean this is plotted, of course, I recognize.

A We have not carried out that calculation. We have one slide, I think, that showed that after ten years the frost -- I think this was an example, that after ten years it would be something like 20-25 feet beneath the bottom of the pipe.

Q Would I be right that if you use the same test you did before, that after 20 years, using the same parameter that you applied on this first example, it would be somewhat larger?

A I don't follow that, sir.

Q Well, you've guestimated or you did a design test and you determined that after about ten years under those conditions you'd have a frost bulb of approximately 20 to 25 feet.

A Yes sir.

Q I'm saying would you carry it on and tell me what size it would be after 20 years?

A I can bring that slide back on for you, sir. I think you could see from there. I just can't remember those numbers, in the order of 25-30 feet, I guess. We've got -- I think we have some examples in the responses to the Pipeline Application Assessment Group on size of frost bulbs,I discuss that matter there; but 20 years, I just

can't give you a specific number. I can put that slide back on for you, if that's what you'd like to see.

MR. ANTHONY: Mr. Commissioner, does that help you at all? The point I was really trying to get at was an indication of the growth of a frost bulb, and we had an example after ten, and it is in various reports, there are other lines sort of zipping out, and I was -- rather than getting into a detailed assessment of whather it's going to be two feet or three feet, I just wanted to deal in lumps of time to indicate in a general sense how the frost bulb will react over time rather than isolating just one year and stopping there.

THE COMMISSIONER: Well, it's up to you. You've just said in ten years, 20 feet.

A Yes sir, ten years, something like 20 feet; 20 years something like maybe 25-30 feet. It grows at an ever-decreasing rate.

Q But it keeps growing?

A Yes sir, it does theore tically for something like 100 or 150 years; but after 20 or 25 years it's growing at a very slow rate.

MR. ANTHONY: Q Now I understand that one of the remedial measures -- I don't have the citation right here -- but one of the remedial measures for dealing with the problem of frost bulb is replacing frost-susceptible soils with less frost-susceptible soils, is that correct?

A That is one method, sir, yes.

Q On page 6 of your canned testimony before us here, one of the tests -- now if -- perhaps you could just help explain and to me if you're ending up with a frost bulb which goes supposedly from zero to 20 feet in ten years, and you're going through a non-permafrost soil, how do you decide how much to excavate so that you don't encounter a frost bulb in that area?

A This is not a proposed technique that we use generally in that particular situation; where we would be replacing frost-susceptible soil with non-frost-susceptible soil would be in the areas -- in rather limited areas, I might add -- say where the pipe comes out of the ground at around compressor stations and that. Perhaps at locations around river crossings and things like that, but not along the general overland problem of a freezing pipe going through unfrozen ground.

Q Dealing with this example and even in the situation, this limited situation, that you would use it on river banks, for example, would I be accurate in saying that if you did that, replace the soil and so on, that you would affect the drainage patterns and so on, would that be a result of changing the soils?

A Well, if you change the soil you change the permeability, clearly, you alter the drainage patterns. Whether you drain it significantly or not is another question; it depends on the specific conditions at that site.

Q Have you also considered the question of, as I understand it, chemical grouting, in other words the injection of chemicals?

A That was an idea we tossed around once upon a time, yes sir.

Q Has it been abandoned?

A Not completely abandoned, sir. It's an extremely specialized technique that we have available in our arsenal of remedial measures, but it's certainly very low on our priority list.

WITNESS HARDY: Mr. Chairman, I am rather sympathetic to that question, as I spent several years in my spare time doing research on the prevention of frost heaving by chemical grouting, and I'm sorry to hear my colleague say here that he doesn't think it was very useful. I thought it was very useful, but the dead end we came up against was the problem of getting it into the soil, and we made a number of pilot plant installations on the railroad, on highways, at curling rinks, and the problem we ran into and as far as I know what everybody else has run into is to get the chemical into the soil. There are lots of chemicals besides lignosol, the one that I was playing around with, that will stop for all practical purposes, the flow of water to a frost line and therefore prevent the segregation of ice; but I never had the courage to toss into the discussions with my colleagues here that that was a viable solution to the problem of frost heaving on

the pipeline

Q Could you indicate what chemicals you're talking about?

A Well, there's a whole series of them, but the one that we were using is called lignosol, which is --

Q Would you spell that for the reporter?

A L-I-G-N-O-S-O-L. Lignosol is actually a trade name, it's produced by a subsidiary of one of the paper companies in Eastern Canada, but basically it's a waste product from the sulphide paper manufacturing operation, and so there are vast quantities of this available on the market which a lot of people object to, and quite rightly so, to having this put into the rivers and going from there into the lakes, and so there's been a tremendous amount of research done in attempting to use these waste products, you see. Well, I was interested in studying frost heaving at that time. This goes away back to the early '50's, you see, and there was -- we selected that one because it was a waste product, There are a whole series of chemicals that will do the same thing and there's been extensive work done, I didn't do all the work by any means, there are many organizations, many universities worked on the same problem and of course you can carry on the chemistry beyond the simple injection, you can inject some other chemicals and create a solid jell, but you still have the problem of getting the chemicals into

these silty type soils that you want to treat. That's why I'm still of the opinion that it's not a viable solution for the pipeline operation, or the pipeline construction.

Q Perhaps then you can allow me to follow it just briefly along. I do this only in the event that your colleagues come around to your proper thinking and to your view, and wish to consider this again. Could you indicate something of the chemical properities of this chemical, what does it do around a pipe, and also what does it do when it gets into the water?

A Well, this is what we were never able to find out precisely, and it gets a little bit out of my field of expertise, but don't think I didn't try. I consulted all my physical-chemical friends where I could get some free advice, and as a matter of fact I even paid for some advice at one stage, and I was never able to get an answer that would be understandable in the sense that we are attempting to make things understandable here.

Q If you don't understand it, I don't.

A But it's associated with this surface tension characteristics, of the chemicals and the effect on the surface tension of water. Beyond that I wouldn't want to introduce --

Q If I can just sort of put a clamp on it so that I understand one of the problems besides whether it works in certain soils and

so on, it's very toxic, is that correct?

A Oh, not lignosol, no. No, you can drink that, but if we start to make it into a jell.

Q And live?

A If you start to make it into a jell then you add chromate salts and they're a bit toxic and there's one occasion where a cow was killed, we think, from that way.

MR. ANTHONY: Now would be a convenient time to break if you like, Mr. Commissioner.

THE COMMISSIONER: We'll adjourn for a few minutes.

(PROCEEDINGS ADJOURNED FOR FEW MINUTES)

(PROCEEDINGS RESUMED PURSANT TO ADJOUNMENT)

MR. ANTHONY:

Q Mr. Commissioner, perhaps we could carry on and I would like to -- we have been discussing the question of frost bulb, frost heave and I would like to now look at the question of frost heave in particular and I would like to look at it in the non-permafrost terrain which is of course the situation that existed at the Calgary Test Facility and I gathered from the discussions this morning that we recognize the general problem of differential heave and the stress that it causes and that different soils heave at different rates, putting stress on the pipe and I gather from your evidence read as part of the prepared text on page 6, you gave four preventative measures and I will just read those. The first one is sur-charging of the ground surface. The second was replacing frost susceptible soil with non-frost susceptible soil, the third was restricting water from migration,and four was reducing the heat flux away from the frost front.

Now, we dealt briefly with the question of frost susceptible soil and its evacuation around the frost bulb and I guess we touched on the third, the restricting water when we touch on something like chemical grouting.

I would like to really concentrate on the question of surcharging which I gather from your evidence is in fact the technique that will be employed throughout the vast majority of

the route, is that correct?

WITNESS SLUSARCHUK:

A Surcharging will be burial, sir?

Q Well, perhaps I will break that down then because I would like to explore that. As I understand surcharging is that in certain circumstances the pipe would float, but that by surface charging or loading, you keep it in the ground and that this is accomplished by two methods: one is deeper burial and the other one is the berm or the surface surcharging. Is that accurate?

A Well, if you are talking about a floating pipe, then certainly if you bury it deeper or if you put something over top of it it will tend to stop it from floating, that is right.

Q Now, let's look at this question of deeper burial and I would imagine that in practical purposes there is some limit to the depth you can go. I would imagine that in some circumstances that may be dictated by the sub-surface, would that be accurate?

A Well, it -- by the sub-surface do you mean something like bedrock, sir?

Q Yes.

A Well, we would be delighted to bury it in bedrock from a frost heave point of view of course. I mean, if we ran down to bedrock, we would not want to go any deeper than that because it would not frost heave.

Q But that is not in fact a practical solution to the problem, is it?

A Well, we have no control where the bedrock is, sir.

Q Well, I understand from what Mr. Williams said one of the problems is that the ditcher, I assume, has some limit on the depth it can go to -- what depths does your ditcher go to?

A Perhaps Mr. Williams can tell you that again, sir.

MR. WILLIAMS:

A These large ditch machines that have been developed have a capability of about ten and a half feet, but there are other excavation equipment that can go down deeper than that.

Q Could you tell us what do you have to do if you want to go deeper than the ditcher goes?

A The standard practice in pipeline construction would be to use a back hoe.

Q Let's look at the question though of the what I have called surcharging by the berm or the question of load method. As I understand the evidence that was led over the last couple of days, what in fact you do is you create a berm or a mound over the pipe by piling up granular material of some sort, is that correct?

WITNESS SLUSARCHUK:

A It does not necessarily

need to be granular material, sir, or select material. All it has to be is something that has weight.

Q And in most circumstances would this be the back fill that is excavated from the trench?

A That would be part of it.

Q And what -- I imagine certain materials are better for this function than others. What are the characteristics that make it desirable to use certain materials for this purpose?

A That they are heavy. You know, all we are looking for is weight and the other criterion is that when we place it there that it does not erode, for example or that you can reseed it.

Q So, for example, if you had a situation where you were going through ice rich permafrost and this was excavated, I imagine that in the summer that would form a slurry and float away so this would not be an acceptable material for this purpose.

A I do not think it would float away, sir.

WITNESS CLARK:

A When you are talking about frost heave, sir, and to interject, the point is that if are going through permafrost, we would not have the frost heave problem to deal with there. It is in the unfrozen ground where we are talking about frost heave.

Q I was diverted into the

question of permafrost on that, perhaps I should not have raised it. I will deal with perhaps the permafrost situation a little later, but in any event, the purpose of whatever material you put on there is to give weight or load above the pipe.

WITNESS SLUSARCHUK:

A Yes, sir, load on to the frost front.

Q Now, you gave us a description yesterday of what you call the shut off pressure which I understand as being the amount of load you would have to put on in a particular circumstance so as to retard the growing of the -- or stop in fact, the development of the frost bulb?

A No, sir, that is not it at all. The shut off pressure is the pressure at which soil upon freezing does not draw water into the frozen zone to grow ice lenses for example.

Q Well, if you reach -- sorry.

A That is all I wanted to say, sir.

Q If you reached the shut off pressure in a particular soil, does that mean that the frost bulb or the 32° isotherm would stop expanding away from that at that time?

A No, sir, it does not.

Q It would keep -- developing?

A Yes, sir, it would.

Q Now, as I understand the range of heave that is acceptable, varies according to whatever construction parameters and so on that you have available, that you have implanted on your situation, is that --

A I chink that we read into the evidence, sir, that it is the radius of curvature that governs.

Q Well, without getting into the technicalities of it, am I not right in saying that what you are concerned with is making sure the pipe stays in the ground?

A Oh, yes, we are certainly concerned about that.

Q And so in some circumstances you would tolerate a heave of two feet or whatever the case may be in fact, if it did not destroy the integrity of the pipe or pull it out of the ground or whatever problem it might encounter.

A Yes, sir.

Q Now we have, if I might just perhaps do it within the context of a hypothetical situation so that we can understand the problem. YOu have a situation of say frost susceptible soil and you have the water you require and so on. You then, I assume, go through a certain calculation and determine the amount of force you need and then decide on what granular -- or what material is available for construction of the berm and then determine the size of the berm?

A Could you just go over that again, sir?

MR. GENEST: I do not want to interrupt my friend, but that form of question is difficult, it has got several parts to it and if I could respectfully ask him to sort of break them down, it would be a little easier to handle.

MR. ANTHONY: I certainly do not want to confuse the panel.

MR. GENEST: It is me that you are confusing.

MR. ANTHONY:

Q Given this situation then, as I understood your evidence that you determine the amount of acceptable heave in a situation by -- and then you determined how much or how large a berm would be required in that particular circumstance to keep the pipe at the location that you determined?

A Yes, sir, I think that is a fair statement.

Q All right. I believe that you gave evidence yesterday that in fact you use as an example in you Calgary Test Facilities of a situation where you had burial at about 10 to 13 feet, in order to have a 2 foot heave over a 10 year period you needed about a 5 foot berm, does that sound --?

A Yes, sir, I think that is what that example said.

Q And I guess too, then

that if you need a greater surcharge or a greater surcharge by way of berm, that what you do is you add more material on the berm.

A Yes, sir, that is right.

Q I am wondering if you would mind, Dr. Slusarchuk, coming to the projector machine here. Prior to the session I asked Dr. Slusarchuk if he would bring out a transparancy which I would then ask him some questions about.

While that is happening, this was not a transparency that was presented as part of the evidence in chief and I was wondering if it should perhaps be labeled as an exhibit and form part of the record?

THE COMMISSIONER: Well, if we treat it in the same way as the others.

A This is the one that you had asked me to put on, is that right?

MR. ANTHONY:

Q Yes, I was trying to get a way that you could bring others along with -- Perhaps you could lower it. Thank you. -- to understand what exactly takes place and I am not going to be relying on the particular figures in any particular detail because it is your slide, but I am merely trying to get some general idea.

Now, am I right in interpreting that slide as indicating what in fact

is the general situation that the frost bulb forms around the pipe at a full and complete circle, in otherwords below, above and all sides?

A. Yes. Would you like me to take one second and see what the slide does show, or do you think it's apparent?

Q Well, perhaps I could follow along in my questioning and you can let me know if -- because I don't really -- I'm dealing with it in a general sense rather than in particular growth and so on. As I looked at that I looked for particularly the uppermost limit of the frost bulb, if I can say so, which is dated the 20th of April.

A Yes sir.

Q And I noticed that that line goes along the surface up into the berm, and then back down below the surface.

A That is correct, sir.

Q And that in fact is the upper limit of the frost bulb at the particular time in your experimentation.

A No sir, that's not correct. In the wintertime it was completely frozen right to the top. This whole zone was frozen, all of this zone, it was frozen from here to over around here, this whole zone was frozen, sir. The 20th of April it's down there because it starts to get warm.

Q Right, so as I understand, what in fact takes place is that as the summer sun hits on the surface, it melts down or lowers down the freezing 32 degree isotherm on both sides.

A Just the same way as it does in your back yard, sir.

Q Right, O.K.. So we have a situation then where the upper edge in non-permafrost soil of the frost bulb goes a certain level below the surface, depending on the amount of summer heat penetration and goes up over the pipe, up the berm, into the berm, back down and then again, depending on the surface, along both sides.

A You can see right here sir, that one month later it's not in the berm at all. It's a foot and a half lower.

Q Right, as I say I'm not using your example, I'm merely trying to get the general point. That is accurate, though, what I've just said, as far as on the 20th of April that's what that line shows.

A Yes.

Q Thank you. Now, would you agree, would you not, that if the berm was higher the upper extent of the frost bulb would also go up higher into the berm?

A Yes sir.

Q So even in a relatively small berm, as you've shown there, you have the frost bulb extending above the original surface of the landscape?

A The frozen zone, sir, yes. We generally call a bulb, we refer to something like this as the bulb and this is part of the seasonal

freezing path of the frozen zone.

Q Well, in any event, it's frozen from the pipe right up through, above the pipe, right up through into t he berm.

A Yes sir, that's correct.

Q I would gather then too, that when you have that extensive freezing, that you in fact have an impermeable layer from above the surface in the berm right down to the lower limit of the frost bulb.

A That's correct, sir.

Q And I would gather, too, that the result of this would be to act as an ice dam, if I can use that phrase, for any cross-drainage.

A Any sub-surface cross-drainage would tend to come up against that, that's correct, sir, and you'd have to flow around there or flow across the top in our berm breaks.

Q Dealing then with the sub-surface for a moment, what do you do to facilitate any sub-surface drainage? Do you just say, "Well, go around the frost bulb," or do you do anything in particular to facilititate sub-surface drainage?

WITNESS CLARK: Perhaps I could answer that. Drainage would relate, of course, to the soil type and the amount of flow, and again getting back to conduction and convection, the shape and size of the frost bulb would be influenced by the flow in the soil type. By and large, for the

condition illustrated there, if it were a frost-heaving soil, it would be very fine soil down where the frost bulb is, so that there would be very little flow. It would be measured in centimeters per year. Up at the top,where there's the active layer, there is more flow there because the soil is not dense, probably organic material. Now that would --there would be a component of that that would be unfrozen all year around. The backfill itself has a permeability that would be several orders higher even than the organic material -- and by "several orders" I mean 100 to 1,000 times greater, so that there would be a cross-flow above that mound that Dr. Slusarchuk points out,directly below the berm. When that is thawed, and if there is any water that rises to the surface, that would be handled as normal surface water that would flow through the berm breaks.

Q I won't get into surface at the moment, and again I extend that to the situation where you have a larger berm because of the pressure you require so that for purposes of illustration, the freezing level under the berm will be in fact quite a bit higher, go quite a bit further into the berm. Now, as I understand what you have said is that the natural sub-surface seepage would in fact rise above that and go around?

A No, it wouldn't flow uphill. It has to flow under gravity except where there is capillary rise,but --

Q So the lower one you would expect would just go under the frost bulb and out.

A The water?

Q Sorry, yes, any sub-surface drainage would -- that was in the lower level if it was to get by the ice dam, as I referred to it would go under-water and out and you don't --

A No. In order for it to be a frost-heaving soil, the flow through it couldn't be very great.

Q Dealing with a level that -- at the upper portion, I should put it -- that the -- but still on the sub-surface, whatever movement of water there was, as it came along it would hit that ice dam which extends up into the berm and would stop, and I imagine the soil -- I don't know if you have sub-surface drainage called upstream, but certainly the direction from whence it came would become more saturated than normally would have been the situation.

A If there was flow there it would be 100% saturated to begin with, and it couldn't become more saturated; but the characteristics of a flow could change and I think I'm grasping your concern here, and that is are we going to block off completely the water that would normally want to flow across that right-of-way?

Q Dealing with the sub-

surface at this point.

A At sub-surface level, yes. Now there are situations that I could conceive that if we took no remedial measures, that that would happen, and that can be handled in,as many cases can be,by different approaches, depending on the consequence. Now one particular consequence might be this one of icings, creating icings. Now we don't view them as a particularly serious problem. As you know the terrain that tends towards creating icings now, there are icings there and I think in fact this week we are doing another reconnaissance of icings along the route, but if we did create an icing or an icing was created where it wasn't acceptable, there are techniques that could be used to induce it to form where it would be excess -- it wouldn't be of as much consequence, and this is a technique, for instance, that's used in the construction of highways, particularly the Alaska Highway, icings have been intercepted. But then if by intercepting this icing, or if by forming a frost bulb in a berm, we cut off moisture that was required down-slope, what we call a shadow, we could, we believe, conduct water through there. Now in order for it to be important, it has to be a fair quantity of the water, as we see it, and we feel that in those circumstances we could pick it up on the upslope side and carry it through the berm.

Q Well, there's a couple of issues there and I'll try to separate that by

dealing solely with the sub-surface.

THE COMMISSIONER: Excuse me. Dr. Clark, just so I understand the thrust of Mr. Anthony's line of questioning, you're chilling the gas in a buried pipeline, and you're chilling it so that you don't melt the permafrost that confronts you with the problem of what happens when that chilled gas is piped through discontinuous permafrost areas where you run into unfrozen ground. You have chilled it to overcome one problem, and you've created another problem for yourselves. Now at the Calgary test site you're seeking to determine what will happen when that chilled gas is piped through unfrozen ground. Mr. Anthony says that the so-called frost bulb constitutes sort of an ice dam, it is frozen ground that is impermeable to water so what happens to normal drainage?

A That's right.

Q Now, if I haven't been thrown off so far, what I don't understand is whether you are saying, "Well, there isn't any water in sufficient quantity to worry about, or else if there is we'll find a way of getting it through the frost bulb so that it can proceed to wherever nature intended it to go."

Now is that where we're at?

A That's right, sir. Perhaps I can amplify on that. Mr. Anthony was talking about flow under the frost bulb.

Q Flow what?

A Under the frost bulb, he was asking if water would come along and flow under it.

Q Yes.

A Now the point I was making there, sir, is that if it is a highly frost-susceptible soil and again he's relating this, I believe, to the fact that we have now put a surcharge on the top, a wider berm is shown there, in order to require that surcharge it would have to be a highly frost-susceptible soil, and if it's a highly frost-susceptible soil, it's a very fine-grained soil, and if it's a very fine-grained soil there is not much water through it, so we wouldn't be counting upon that as a solution. We wouldn't in effect be saying, "well, the water can come along and go out underneath and up the other side." It's just not a viable solution.

So the concern then relates to the very near surface flow, or the surface flow, and this is an area where we would have input from our plant ecologists. They could look at the surface flow design measures that we have, some of which I illustrated yesterday, and if that did not satisfy the re-distribution of moisture on the other side of the right-of-way, because you see it depends on how the soil there gets its moisture, whether it's predominantly sub-surface flow or surface flow.

Now, if the drainage measures did not satisfy it -- if there was subsurface flow of a significant amount, we believe that we could carry it through the frost bulb, because we can move a fair quantity of water without having it freeze. If it was a very low amount we would have difficulty moving it through because it would not go through fast enough and there is a good chance that it would freeze. So the point I am trying to make is that where there is a significant amount of flow, it can, we believe, be carried through that zone where it is frozen and that would only be required where we had a surcharge such that it might cut off that area of normal flow, did I answer your question, Mr. Anthony ?

MR. ANTHONY:

Q Well, in part -- I will split up a little bit. The one about the going under I will deal with quickly because it is not my prime concern, but first of all I understand an aquifer is the layer that the water would be flowing through or under if there was subsurface movement.

A Yes, sir.

Q Now, my understanding also is that aquifer can be underlain by frost susceptible soil--

A Yes, sir.

Q -- so, I do not understand if that is in fact the situation why it is im-

possible for -- or for example, the frost bulb to extend across an aquifer below the frost bulb.

A I certainly did not intend to indicate that that was impossible -- that could happen, yes.

Q Okay, fine , so there is the one problem that we have isolated, fine.

Now, dealing with the part at the surface we have again the situation where the frost bulb is above the surface, of the original surface and as I understand your response to that, is that two things will happen. Either the water will build up and then come on the surface and then we can talk about that in a moment, or alternatively I believe you said that there is a method of conducting that water to the shadow, to the other side of the ice dam.

Now, would you tell me what techniques you use to do that?

A I thought I had, sir. The point is that if there is a significant, a fairly good aquifer close to the surface and it was required to get water from one side to the other, we feel that with an insulated conduit It could be picked up on one side and redistributed on the other. -- And carried through.

Q That would be taking an insulated pipe, shall we say, through the frozen frost bulb or the frozen area in any event?

A Yes, sir.

Q And you are satisfied that by putting pipes through that, the water will not freeze and block the pipe and have the same problem, is that it?

A If there was a very small flow that would happen. But if there is a very small flow it would not be required to do that, I feel

Q Okay, so we deal with it then, when there is a small flow you would not do anything and you would let it build up and on the side because it would build up rather slowly?

A Well, yes. What you are looking at there is one section through a pipeline and you are looking at that top isotherm with the mound on it. Now, if you look lengthwise and follow this down, that mound is not a straight line, it is like the permafrost table, it is up and down and where it is down, the water would go through and where it is up, it would not.

Q As I say, I did not want to get to where the water is above the ground. I still wanted to deal with --

A I am talking about also subsurface, sir, as well.

Q So in that level then you would -- if it was a significant flow you would put a pipe through the frozen area and the flow would be sufficient that it would not freeze?

A If it was a significant flow. The pipe could be well insulated through that

area and -- that is amendable to a design,to a calculation, to an analysis.

Q I may have missed this or people who I was discussing this with -- could you tell me what experiments you have done in with using this technique and how successful they have been and --

A I do not know of any application of this technique simply because it, to my knowledge has never been required, but the --

THE COMMISSIONER: That is the insulating of the pipe so that it does not chill the unfrozen ground. That is the technique you are speaking of now.

A The insulation that I was talking of, sir, was the insulation that we would put around the small diameter pipe tokeep it from freezing --

Q Oh, I see, yes --

A That has -- there are endless examples of that -- waterlines and so on.

MR. ANTHONY:

Q Well, I myself cannot pursue -- evaluate that, but I am wondering if you would perhaps advise this Inquiry of the studies that have been conducted on this technique and the results of these studies and perhaps if there is some significant question we can discuss it at a later stage --

A I should make it clear that there have been no studies -- or tests done with a

chilled pipeline of conducting water acrossed across a frost bulb. What is a common practice is to insulate water lines and swerer lines where the ground might freeze them.

Q WEll then, perhaps we could still get that information and try to interpret it and if I understand it, the technique of actually putting an insulated pipe across the frozen thing has not been experimented on?

A The techniques of insulation are so well established that it is almost like going back to Archimedes Principle on bouyancy. I am not sure what kind of data you are looking for, sir. If you are looking for properties of insulation and tests like this I am sure that we can get that from manufacturers and examples of where they have been, insulation has been applied to pipes.

Q Okay, so that I understand it, you are saying that there is a general knowledge about insulation properties of pipe and so on and that you have not in fact experimented with actually using a pipe in this situation --

A No, there has never been an opportunity to do that.

Q Thank you. Now, let's now go to the situation where a flow is either minimal or your flow through pipe does not work and you have the situation where the water builds up on the upper slope of the berm, because of the

damming effect of the frozen area. Now, I would assume that if it was not at a saturated level above the pipe when it started, it would become saturated and the water would then come to the surface, is that -- in what you described as an icing or a forced icing?

A Yes, an icing could develop there. I should also point out sir, that in our assessment of, to what extent we would deal with some of these aspects in phase one, we viewed the impact, what you are getting to, as Phase two in the water stage, and I am not a hydrologist and what I am passing on largely is data from Dr. Harlan and he could, I am sure, amplify on several aspects of this because he has done experiments and studies in the north on ground water behaviour and --

Q At this stage at any event and before getting into the problem of whether an icing is good or bad, at least we have got to the stage that that is what will result.

A An icing could result, yes.

Q Now, am I accurate also in saying thatgiven that situation again, or even a further protruding frost area under the berm, that there was surface drainage coming down -- again I am assuming that it is a slope -- the surface drainage that would come down, as I understood your evidence yesterday, would then be diverted through the techniques you described through cuts in the berm and

then allow it to continue on.

A Yes, sir.

Q Now, I would imagine then that if you have got a frost bulb protruding for some distance above the surface into the frost -- into the frost area, that any surface water that was diverted across the berm at that point would also cause icing?

A No, I do not believe that that would be the case.

Q Well, then let's explore that.

I look at that and I see a situation where the frost or the frozen area under the berm extends above the surface and you are diverting -- you then cut into the berm. That is correct?

A That is correct.

Q So assuming you would then cut it then down to the surface level to allow for this cross drainage. So using that example, there, you would cut the berm down to below where it would normally be frozen. Now if you had not touched the berm, there would be a frozen area, but in fact you have excavated the berm at that point to allow for cross drainage.

A Yes, and if I could go back to my example, if you took the top of that line there that we are looking at in section and followed it along the pipe, it would go down where there is a berm.

Q Of course it may not go down at the place where you want the water to cross. It may not go down as a matter of fact for quite a distance.

A But the fact that there is water there to conduct means that we are talking about summertime. Or if you are talking about the spring runoff which as Professor Church pointed out, represents about 50% of the annual precipitation and then of course all the ground is frozen and it is just a case of running over frozen ground --

Q I appreciate all of those things, but -- let's go back again to the example. If you have a high berm with a high frozen area underneath it that extends for some considerable length because the pipe is buried at five feet and in fact the frost bulb has extended to quite a height and you would have to surcharge it. You have quite a dam that extends above the surface. Now, it is possible, I would suggest that you may want to cut across that berm to allow for surface drainage.

A Those cuts would be established at the time the berm was built. I think that that might be the misunderstanding is that you are assuming that we would go in and cut through a berm that is frozen.

Q Well, I am saying that there is the possibility is there not that that either may happen or that because of the surcharging

you require you are going to tun into that problem in any event?

A ONe could speculate that that could happen. We have gone in now on this situation and I cannot visualise, but I can speculate that -- and we have cut into a frozen berm to let water go across, that is the point where we are at now, are we?

Q Right.

A Fine.

Q Now, that surface water would also cause an icing as it crossed over the pipe area?

A Oh, no -- no. It is bringing in heat with it. The fact that it is running, it is not frozen.

Q So do I understand your evidence that as the surface water cutting across the surface of a berm where normally it would be frozen above it, would not freeze?

A Well, as soon as we cut that berm and expose the frozen part, that is going to start to melt.

Q Okay and --

A And the water will probably cause it more melting because of the convective heat aspect.

Q So your evidence is that in any event that as the surface water goes over an area in the situation we have described, it would not

freeze?

A In the context of the scenario that you have described, that is correct.

Q In what condition would the surface water freeze then?

A If it was stopped there. If it was ponded at that berm break, but if it was flowing, I cannot see how that, during the summertime, when there is rain, that is where the surface water comes from.

Q What about in the summertime when there is just a very, very light flow. The surface water is not one that would either come washing down the mountainside with a greater amount of heat and force, but in fact is just a very light surface trickle. Perhaps you can wait until I finish my questioning on this and then you could perhaps expound on it if you wish but --

A Certainly the water that would be below the 32 isotherm would freeze, but in the summer time that isotherm would not rise above the ground.

Q In that circumstance you say that there would not be a frozen isotherm at the surface?

A Not in the summertime, sir. Perhaps Dr. Slusarchuk could illustrate with a sketch that he has very quickly developed that would

schematically show what we are talking about.

WITNESS SLUSARCHUK:

A This is our pipeline running along here --

WITNESS CLARK:

A That is very schematic, I might say, sir.

WITNESS SLUSARCHUK

A This is our berm. The top of our berm right over the centre line of our pipe and the original ground surface for example, would be somewhere about here. Your point, sir, is here. Your point, sir, as I understand it -- this was the original ground surface and it is now frozen above that due to the cold pipe and because we have put the berm on top and you are worried about, or you are concerned about water flowing in this direction, say, and being dammed here because it now would like to flow down here, is that what I understand ? And this is the berm break that we are talking about, additional ground surface is now here. Without even considering whether or not warm water is going to melt, or cause further melting across here or not, the natural sun itself as it started to thaw here and would simply thaw down beneath here as well. So at the berm break, we would in fact have the frozen zone beneath the natural ground surface at that point.

Q The point I was perhaps getting at, and that's helpful but now assuming that there is some surface run-off commenced, and the sun hasn't thawed down the frozen area to the dotted line but in fact the frozen area -- and I think the one thing I would disagree with on your diagram is that in fact I would assume the berm on the left-hand side would go up again, so that you have --

A Yes sir, that's right. I meant it to be the same height.

Q Right, so that you've got that left one just as high, and you have the dotted line coming, going down around where the berm break is, and then going up again.

A Yes sir. I meant this part to be a mirror reflection of that part.

Q I am merely enquiring as to whether or not it is possible, in fact, that the melting within the berm break may for example an accumulation of snow in there, or for some other reason that the sun cannot penetrate, would in fact melt at a slower rate and therefore still in fact be frozen right at the surface where the water would normally traverse.

A I see your point, sir.

Q And that is possible, I gather, if the sun didn't melt it right at the berm break it would still be at the surface level and the water would freeze.

WITNESS CLARK:

A The water is moving, sir, you had it blocked with snow and you also had water.

Q I'm going on the basis that -- don't throw me off because I don't think --

A I'm not trying to throw you off, I'm trying to understand you.

Q There is a situation where the dotted line would go right to the bottom of the berm break, and I'm saying that there is the situation where the sun has not melted below the berm break level, so that that dotted line in fact goes straight at the bottom of the berm break. The sun has not melted it any further down.

A Oh, I see.

Q Now in that circumstance the water, as it went over that, because somewhere up the slope it had started to melt already, even though it hadn't melted in the berm break, it would in fact freeze.

A No, again we're mixing two things together, and I'm not trying to be argumentative; but if the sun hasn't melted it, that means that the run-off that we're dealing with is snow. You would agree to that?

Q No, no, I'm not saying that is it not possible there could start some run-off up the slope that would come down at a time when the sun hasn't melted the berm break so as to move the -- to have an unfrozen area under the berm break.

Do you see that?

A I can't conceive that happening because we're really talking about snow melt, if the sun hasn't melted it.

Q Well, perhaps we're obviously, I think the point is clear; if we can't agree as to whether or not it's possible --

A Another point that I think is significant here is that I showed yesterday that at those berm breaks the soil is gravel. Gravel has a lower latent heat than a fine-grained soil, and therefore it melts faster, not slower.

Q Well, I won't get into arguments as to whether it's possible to have, for example animal passage or any other reason, a compaction of the snow so that the sun doesn't get at it. I'm getting at the question obviously of differential melting and the fact that it's possible to have compaction of snow or any other reason, the berm break doesn't melt at the same time that the untrampled snow up is melting; but as I say if you can't follow on it, why I'll let it go.

THE COMMISSIONER: Mr. Anthony, just a moment ago you said the point is clear. Would you tell me the point that you understand is clear and just so that if Dr. Clark or Dr. Slusarchuk don't agree we will know; if they do agree we will know.

MR. ANTHONY: Well, the point

that I was attempting to establish, and I thought at one stage I had a glimmer of recognition, was the fact that it is possible under certain circumstances where the sun doesn't melt the berm break area as fast as other areas, that in fact the frozen level will be right at the surface. Therefore due to this differential rate of melting there may be some surface flow that hits this berm break and freezes, because the sun hasn't penetrated below the berm break. That's merely the hypothetical situation I'm creating. That may be helpful, I don't know.

WITNESS COOPER: The situation you're referring to when we get water flowing down the berm and then across a frozen portion of the berm break, O.K., for that water to freeze it would have to be essentially at 32 degrees itself, and we would have to have the frozen berm at several degrees below 32, otherwise even a part of one degree above 32, if the water is at that temperature, it will tend to melt the berm break rather than freeze itself. Now we've got any number of examples of channels cutting -- actually cutting their way into off-ice areas where you've got a surface temperature that would be below 32, and they will erode through that rather than freeze.

Q The only point is that this is possible that situation could arise.

A No, I don't think so. It would be -- the water would tend, in the situation you've portrayed, to melt the berm break rather than

freezing itself.

Q O.K., then we'll obviously have to do without that one. Let's then go on and that's fine, Dr. Slusarchuk, as far as those diagrams are concerned, thank you.

Let's deal then with the situation in permafrost soil now. Now I wasn't clear from Mr. Williams' answer this morning as to whether or not the Sans Sault test facility included experimental design techniques necessary to measure and calculate frost heave in permafrost. Could you tell me whether that facility was designed to test for those sorts of things?

WITNESS WILLIAMS: That was not designed to test the frost-heave phenomenon, no.

Q Well, then, merely I would just like to get some information, if that facility in fact didn't deal with that problem. You state in your response to the Pipeline Application Assessment Group concern No. 8.1 on page 3 of your responses, there was the question of frost heave around pipe buried in permafrost. Your response is:

"From the studies we have undertaken for the applicant --"

MR. GENEST: Can we find that?

MR. ANTHONY: It's in the canned response by the panel to the Pipeline Application Assessment Group. Page 3. Mr. McRoberts is

whispering in Mr. Williams so he may be the one to respond. The response is as follows:

"From the studies we have undertaken for the applicant, it is our view that water migration in permafrost due to operating the pipeline at below freezing temperatures would not produce significant heave during the life of the pipeline."

Could you tell me which studies you were referring to with respect to experimentation of frost heave in permafrost?

WITNESS SLUSARCHUK: These aren't referring to experimental studies, sir, they are referring to -- not wholly to experimental studies. They are referring to analytical studies that we have undertaken as well. I might add that although the Sans Sault test facility was not designed for testing frost-heaving, as Mr. Williams said in permafrost, in fact we can make use of the data from there to help us out in that. They had risers attached to the different active sections which he described they were operating at the different temperatures. They have made elevation surveys and we have the results of those surveys, and over the two-year period that they were run, sir, we cannot detect any noticeable rise of the pipe or frost heave due to operating the pipe in permafrost.

Q. Well, there are two issues I addressed myself to. The first one is you didn't test for it but you didn't find it, is that

what you're saying; at the Sans Sault you did in fact design a facility to test for frost heave in permafrost but you didn't find any.

A No sir. Mr. Williams, sir, said that that was not an objective of the test facility. I am saying that although it was not an objective of the test facility, there was enough information obtained and the proper instrumentation put in, and elevation surveys run, so that in fact we could make use of it as a test facility for frost heaving in permafrost.

Q Do I have your opinion then, Dr. Slusachuk, that on the basis of the design technique and the information you obtained you are in a position now to discuss the amount and significance of frost heave in permafrost?

A I understood this was what I was saying, sir.

Q I see, and do you feel any further study is required to determine frost heave in permafrost, or have you got enough information now?

A No sir, my opinion is that frost heaving in permafrost is not a significant engineering problem to us.

Q And you've come to that conclusion on the basis of the information that you now have?

A Yes sir, that is correct.

Q Let's look for a moment though at this question, and I know, Dr. Slusarchuk, you didn't do any experimental work or field work on the question of permafrost or frost bulbs or frost heave in permafrost, your work being involved in the non-permafrost area in Calgary. But I'm wondering if perhaps we could operate on the type of analytical extrapolation you suggest and try to get an indication of what in fact the frost bulb or the frozen area around a pipe in permafrost would look like?

I imagine then that in permafrost the frost ridge, if you want to put it that way, would similarly extend up the berm.

A You're just talking above the pipe now, sir?

Q Above the pipe, yes.

A Yes sir, above the berm of the backfill, we're certainly not planning any surcharging up in that area, in that point.

Q So you're just talking about the berm of the backfill?

WITNESS CLARK: The spoil mound, yes.

Q The spoil mound, so in any event, without getting into technical detail about heights and widths and so on, there would be, if I may characterize it, as a ridge of frost above the usual level of the permafrost level into the active layer?

WITNESS SLUSARCHUK: Just for a very small portion of the summer, sir. The spoil mound is not high, and if we are shown that there is an active layer over top of the pipe at the field test facilities, both at -- well, at all three of them, Prudhoe Bay, Sans Sault, and Norman Wells -- it's certainly there for a part of the time because it freezes right to the surface on the top and it takes a finite period of time for it to thaw down. It thaws down through that top foot very quickly.

Q But what I'm getting at, though, is that at the spring, for example, you have a situation where everything has been entirely frozen all winter, and as the sun comes it melts the active layer on both sides of the berm and the top of the berm, with the result that there is a ridge, as you say, for perhaps only part of the time above the pipe, underneath the backfill berm.

A We're talking about time length maybe several days to a few weeks.

Q But I suppose if you had a higher backfill or a higher berm, that the ridge would be higher and last longer.

A Dependent on -- it also depends, sir, on the depth at which you buried the pipe; the deeper you bury the pipe, the less influence it has on the position of the thaws above it because the energy from the sun coming into the ground surface dominates the cold, if you want to put it that way, that's coming from the pipe.

Q But given the situation of a determination of the depth of burial and then by some inexplicable reason there is frost heave in permafrost, and you have to surcharge on the top, you'd increase this ridge into the active layer, would you not?

A We are talking an extremely hypothetical case, sir; we have no plans for that whatsoever.

MR. GENEST: Well, Mr. Commissioner, that to me is impossible. The question is prefaced by the terms that "due to some inexplicable situation". I don't want to interfere with my friend's cross-examination but I don't think that sort of question gets us anywhere. It's impossible to answer.

MR. ANTHONY: Well, Mr. Commissioner, we discussed because there were experiments done, of the building up of an ice dam underneath the berm in non-permafrost soil, and I am merely suggesting -- and while my friends admit they haven't studied the point -- that the same situation would develop in permafrost soil, that there would be a ridge under the berm into the active layer, the extent of which and the duration of which we don't really know.

WITNESS SLUSARCHUK: No sir, I didnot say that. I thought I was very clear that we had studied that, and we've got experimental evidence from our field test sites and from our geothermal analysis, some examples of which are in the application, additional responses to the PAAG, and what you are suggesting it just doesn't seem to be correct, sir.

MR. ANTHONY: Q But did you not say that in fact there would be an ice ridge into the active layer above the pipe for whatever duration or however you want to complicate it or limit it, is that not so?

A Yes sir, we said that.

Q Thank you; and I would imagine, sir, Dr. Clark, and again I'm just trying to get a simple answer to the thing, if there was a ridge into the active layer, this would have an effect on cross-drainage across that pipe.

WITNESS CLARK: For the period that ridge was there it would.

Q Thank you. Let us now again look at this question of the frost bulb but let's look at it in the context of river crossings. Now I believe the evidence has been led that under rivers or large rivers in a permafrost area there is in fact no permafrost, we're dealing with a non-permafrost situation.

A That's correct, yes.

Q And we have discussed in the evidence before this Inquiry about flow characteristics of such rivers as the Malcolm River, for example, on the north slope of the Yukon. Now I believe that as a result of those discussions I'm accurate in saying that in those rivers, for example, or in that river, for example, dealing with it as an example, that in winter often it is freezing right throughout -- at certain portions -- throughout the whole depth of that river.

A I would think that in certain braided portions that would be the case, yes.

Q As a matter of fact, in case you wish to refresh your memory, I would refer you to the biological report series which is the supporting information of the Arctic Gas application

Volume 16, page 9, which suggests that in fact it does freeze at portions right through to the bottom.

A Yes.

Q And perhaps we can take it as given until we get into the later panel, but I would put it to you that in fact, upstream from proposed crossings of the pipeline there are over-wintering areas for Arctic char and grayling and so on.

A I'm not aware of any upstream over-wintering.

Q Downstream, sorry.

A I believe that has been suggested that there are over-wintering areas.

Q Again I can refer you to some of your own consultants, McCart, 1974 and 1975.

A Yes.

Q And also because of the fact that there are these over-wintering areas, the suggestion is in those reports and perhaps we can just take it as given until you have a chance to refresh your memory, or examine these questions, that there is -- this is due to what we call sub-surface flow in the river, and so that I understand what I've just said, that because in the wintertime the ice freezes right down to the surface of the river, that this water which gets to these over-wintering areas, and supplies the fish and so on, in fact percolates through the river bed.

MR. GENEST: I thought I understood my friend until that last one. I don't know what he means by the water freezing to the surface of the river.

MR. ANTHONY: To the surface of the bed of the river.

MR. GENEST: Oh, sorry. Yes, I understand.

MR. ANTHONY: Q Dr. Clark, you and I understand each other?

WITNESS CLARK: Certainly.

Q It's wonderful to deal with technical experts. Now you put your pipe underneath that river.

A Yes sir

Q And you create the frost bulb, and I invite you to agree with me that it is possible that that frost bulb around the pipe and the ice on the river which comes right down to the surface of the river bed could meet or almost meet.

A Yes, I stated that yesterday, sir.

Q The result being the same ice dam problem for any sub-surface flow.

A Yes, if they meet there's a possibility, but if there is any flow above the bed our studies indicate that even at very small flows that gap won't close off because of the pipe; but where they meet, you're quite

correct, I did state that yesterday.

Q So again we're stuck with the ice dam problem.

A Yes sir.

Q Blocking off any down-stream flow to the fish and so on. Now besides that effect on drainage, which I don't want to reiterate again, there is the possibility of icing created in this situation also, isn't there?

A That's what I used as an example, I think, in my earlier testimony, yes.

Q The water would build up and come up to the surface, causing an icing on the river.

A If no remedial measures were imparted to the pipe there.

Q Now I think in your evidence when you dealt with this you discussed the question of a culvert.

A As a possible solution. Again putting all the factors together, that is the over-wintering fish, the need for water, and the oxygen,there has to be a significant flow through there for all those circumstances to permit fish to over-winter, and if they count on flow through that aquifer or gravel bed, then there has to be a fairly significant flow through there to meet their requirements. That's my understanding of the situation.

Q And the technique of

the culvert would apply to both, any sub-surface flow or below the riverbed flow as well as any minute flow that's still going --

A No sir, only for the below the riverbed.

Q Now if we can believe your report that there is no -- that it freezes at some points right down to the bottom, and there is only the sub-surface flow, how do you deal with that problem?

A Taking the situation now where we're frozen right down to the river bed, maybe a bit into the river bed, and the unfrozen zone between the seasonal freezing and the pipe has now coupled, come together so that we have a barrier there, and it would be a trumpet-shaped barrier, which I'm sure you can visualize. Our proposal to solve that problem would be to pick up water upstream of that barrier below the bed, not above the bed, and to carry it below the bed through that coupled area and re-deposit it at the other side. Is that clear, sir?

Q I think I understand you. Would I be right in saying that you'd use the insulated pipe technique that we discussed when we were talking about going through a berm?

A Yes sir, yes.

Q Let's talk a moment then about this question of icings. Now when an icing is created, as I understand, the real problem on it

is that in the spring run-off it causes an ice jam, or it in fact remains stationary while places which are not subject to icings will melt. Is that one characteristic of an icing?

A That's correct; and if it lasts -- some of these, of course, these occur naturally and some of them last through the year and the term often applied is aufies, A-U-F-I-E-S.

Q Now a sudden release then of -- or an icing then could have the effect of holding back or retarding the spring run-off. That's a characteristic of that?

A The answer is -- well, I'll let Dr. Cooper speak to this.

WITNESS COOPER: No, once you get spring run-off, of course coming into the river channel itself, it would flood the icing and in most cases would erode through that icing. In fact there are many illustrations or it's been observed in many cases of meandering channels cutting their way down through significant icing deposits. For example, on the Canning River.

Q Well, so I understand it, what happens is the ice sits there and when the water comes it will either go over it and around it or it will go under.

A No, not under. Don't forget with an icing you've got solid ice from the ice area interface right down and it's frozen right

into the bed.

Q Now if you had a minor flow under the ice, at any stage, would there not be -- would not the hydraulic pressure in fact force this going underneath the icing?

A If you have got a minor flow you can get, I believe, some tunneling, but the question I think you have to ask at this point in time is, where does the flow enter the system and if your icing extends upstream and you do have a significant flow entering, it is going to pass over top of the icing. It is important to keep in mind that the rivers where icing occurs are very steep. They will have gradients approaching 1%, say a half to 1% downstream gradient which is a fall of about a foot in a hundred, so it is not that difficult for the flows to go over top of the icing and then erode their way through.

Q I guess the question boils down again into my simplistic terms as to whether or not you can have the possibility of scour that you described yesterday under an icing.

A The observations that I have been made aware of through various discussions of icings and their phenomena in Alaska, indicates that for a natural icing, or for an icing that might be induced by the cold pipeline, that the only potential for scour would be where you had a channel coming over top of the icing and then dropping into a hole and that level of scour would be rather minor, it would be in the order of four or five feet, but these have been observed, yes.

Q Maybe, so I can tie it together in my mind, we have the situation where an icing may exist as a result of the pipeline and now

what you have said is that it is possible that as a result of this icing, there is a possibility of scour if some other conditions exist, is that what you are saying?

A Well, there is a possibility of some very localized scour but it would not be extensive and it would certainly not get down to the level of scour that we are coming up with, with other considerations for the purposes of design of that pipeline.

Q But if you had a very -- if the icing was located at just the right point so that as the water came over it came down and scoured righton top of the pipe, if you had a heavy enough flow, is it not possible that scouring could occur where the pipe is?

A The type of scour that I am talking about is of the nature that it just could not get that deep, because once that flow drops down, then it has got to go somewhere. It is not going to go down, it has got to dissipate further downstream, okay, and to do that it has got to have, if you like, a water level within that very isolated hole that is sufficient for the water to continue on downstream.

Now, with that water level, you get essentially energy dissipation which -- it limits the depth of that very localized scour hole.

WITNESS CLARK:

A Perhaps you could

maybe clear a point, Mr. Anthony, so that I understand it. We are dealing with the situation where we have frozen the gravel and caused an icing and now you are asking us if that frozen gravel will scour preferentially, the frozen gravel that caused the icing?

Q We weht, first of all for the purposes of establishing the fact that an icing is possible and the question I directed to Dr. Cooper was, if the icing was located in a particular spot, would there be a possibility of scour where the pipeline is located and I think that's --

A The gravel is frozen there as well which would even make it more resistant.

Q Well, let's consider then the phenomenon in another context and that is the context of an ice jam and I understand from the evidence that was given, I believe by Dr. Hollingshead who discussed ice jams or flows, that in fact they can be created at almost any location, is that accurate?

WITNESS COOPER:

A Are you still asking this in reference to a river type like the Malcom?

Q Well, perhaps we could deal with it more generally, because I do not want to have to go through the same thing with various rivers. Perhaps you could tell me whether in fact it is possible to have icings in almost any location in rivers such as the Mackenzie, the Peel and --

A Fine, I think I had better

clear up any miscon -- or confusion that might exist with regard to normal river ice processes and what we refer to as icings, because they are two quite separate phenomena. Now, in the Mackenzie River, the processes that occur are admittedly quite severe, however, they are normal river ice processes. When the river ice forms, it forms a cover and there is still a significant flow underneath. In the case of the Mackenzie River, even in mid-winter it would be over 100,000 cubic feet per second.

On the other hand, in the case of the north slope rivers which are braided, we get virtually zero flow above the river bed during winter and when winter comes on there is almost negligible open channel flow, if you like. We get a freezing of the bed, if you like, and we get water being forced up onto the surface where it freezes and that is how an icing develops.

The ice jam concept that we talked about yesterday, can occur only in the type of river where you have the normal icecover and you have a flow of water underneath it and a significant flow of water. So we feel that the ice jamming problem is of concern only on the very large and essentially single channel rivers such as the Mackenzie, it would be a consideration on the Liard River, it would be a consideration on the Peel River and on possibly rivers like the Willow lake and the Great Bear.

Q Giving the situation then where an ice jam is possible -- and I will deal with an ice jam, and I thank you for making the distinction clear, I gather that in those rivers, for example, the Great Bear and so on, it would be possible for an ice jam to be created, for example, right above a pipeline crossing?

A Yes, this is a possibility.

Q Now, what I am trying to perhaps understand is we have a situation now where you have got an ice jam above the pipeline and you described yesterday the force of the water going underneath causing scour. At the same time you have the frost bulb on the pipe around the pipe in the -- below the river bed.

Now, you gave us calculations and formulas and reports yesterday with respect to the likelihood of that scour affecting the pipeline, and I was wondering, I guess, whether you included the possibility of the element of a frozen pipeline in your calculations and whether that in any way affects your predictions?

A No, I did not in my discussion yesterday. I can however, comment on what the effects would be. If we were to bury a pipe up within the -- at a level such that the scour would develop to below that pipe -- we are not going to do this, but let's paint the picture where we would and scour then develops down and around the pipe.

What the pipe does is it acts as a barrier to the development of the scour. We get a ramp of sediment -- now I am going to go from upstream of the pipe and through the scour hole and we get a ramp of sediment that has quite a general slope, going up to the top of the pipe. We then get another ramp of sediment downstream within that scour hole. The only way you can get loss of support material underneath the pipe is if your normal depth of scour would be deep enough that you would get it essentially piping failure or loss of the current passing underneath the pipe and washing out the support material.

Now, we have several years ago been involved in some model studies that -- hydraulic model studies -- that indicate that that scour hole would have to develop to the level of the bottom of the pipe or somewhat below that before we would get that washout. So in answer to your specific question, the effect of a frost bulb around the pipe is going to make it a safer situation because effectively we have a larger diameter pipe. So the frost bulb in the even of scour, providing it stays frozen, and as I indicated earlier, the water may actually decrease the size of this frost bulb; providing it stays frozen, it is actually an extra margin of safety against scour -- one that we are not taking account of in our design.

Q Assuming then that after a few years of operation you have a four-foot pipe and a two-foot frost bulb situation, what

you are saying is that unless the scour hole is more than whatever distance it is to the river bank, plus that ten feet, it would not affect the pipe?

A No, from the point of view of the flow that is causing the scour, it would look at that situation as if it was looking at a six-foot pipe rather than a four-foot pipe.

Q But a scour hole more than say a scour hole of twelve feet, for example, or fifteen feet, if it was to be created, would then get into that sort of problem that you described?

A Well, yes, of course, if the scour hole was to develop to well below that frost bulb, but of course we are taking this into account in our design. As I said when I painted that example, that we would place the pipe up within the scour hole. We are definitely not going to do this in our designs.

THE COMMISSIONER: Dr. Cooper, are you saying that where you have the pipe buried beneath the river bed and a frost bulb develops around the pipe, that you do not have to worry about scour, owing to velocity of the river and the force of the flow being diverted by an ice jam, because the frost bulb cannot be diminished by the scour?

A No, I did not say that. I said that the effect of the frost bulb pipe configuration, should it be up within the scour hole, which is a situation that we are not doing in design, but

should it be up there because I was responding to a question of what is that effect, it is to hold the bed at that location. The bed would scour upstream and downstream to a lower level. But the frost bulb itself is a feature that would maintain that bed at that location.

THE COMMISSIONER: Well, are you saying that the force of the water scouring the river bed would not cause any change in the condition of the frost bulb?

WITNESS COOPER: No, I'm not saying that. The water itself may have an effect when it got onto the frost bulb of actually melting the frost bulb and decreasing its size from the top.

Q And exposing the pipe?

A Should these conditions go on long enough, and again if we were up with the pipe, which we don't want to be, and I want to emphasize that, yes, you could expose the top of the pipe.

MR. ANTHONY: If I may just look a moment at the question of water crossings, dealing with a particular example that was touched on in your evidence with respect to Shallow Bay, and we may have to have the same problem of waiting for material to get into any great depth, but I would like to deal with a few questions while I have this panel before us and in view of the fact that it's -- some of the information I'm relying on is part of the reports that your panel are relying or referring to, I say that by way of preliminary comment so that we don't defer any shuffling to another panel. Looking at the question of Shallow Bay, I understand that from the evidence that was adduced yesterday that in fact there were some test profiles done of the crossing, of the proposed crossing on the cross-delta route.

I believe that in fact there were some soil samples done, I think Dr. Cooper or Dr. Hollingshead referred to this yesterday. I was wondering whether in any of the core sampling done in the Shallow Bay crossing whether you encountered permafrost under the crossing you propose to use.

WITNESS CLARK: There wasn't, to make it clear, and I don't want to quibble, we didn't actually take cores in Shallow Bay, mainly because of the type of information we wanted at that time didn't require it. It's quite a different technique to get a core than to drill a hole and look at the cuttings, so we drilled holes there in Shallow Bay, yes, and as I recall, there was within the depth that we drilled, no permafrost encountered, in the water area.

Q I understand, though, that the soil or the situation of the soil under Shallow Bay would be defined as fine-grained soil, is that --

A Yes, it's a sandy silt and a silty sand.

Q Do you call that a frost-susceptible soil?

A It's -- yes, it would be called a frost susceptible soil but we're comforted by two facts, (1) it has a very low shut-off pressure or at least normally has a very low shut-off pressure, (2) and the other is that it's a very recent deposit

and it's not consolidated.

Q Given this frost-susceptible soil then, I would assume that you can't construct a berm under Shallow Bay. Could you tell me what techniques are used for example to prevent frost heaving in that situation?

A Well, the potential for frost heave and magnitude hasn't yet been assessed. This is a part of our future program. Our preliminary assessment is that it won't be too significant, and Dr. Slusarchuk touched on some of the reasons why in his presentation. As I mentioned, it's not consolidated so that where ice lenses form, they consolidate the soil rather than heave the pipe. In other words, they take the direction of least resistance and the least resistance is to consolidate the soil rather than to heave the pipe.

Q When you talk about consolidating the soil, I assume that's what we've been talking about by way of surcharging, is that --

A No sir, no.

Q How do you -- perhaps then we can just deal more generally. Can you tell me then how do you deal with the problem of, we now have non-permafrost soil, as you have indicated, how do you deal with that problem of potential frost heave under a body of water like Shallow Bay?

A Well, it would vary from body of water -- you see, it would be different in

rivers than in Shallow Bay. In Shallow Bay the design that we have proposed for preliminary work that has been done, we propose to bury the pipe crossing there at at a depth of 10-20 feet below the ice, or ten feet below the bed of Shallow Bay, whichever is greater. This would be dredged out. We then propose to blanket a certain area there with gravel. Now that has been a tentative proposal in order that it could be built into the cost estimate, should it be required. We won't really know whether that would be needed or not until a later stage in design. But if a frost heave problem is developing under a river, or a potential exists under a river, we have some of the alternatives available to us, one of which is not surcharging. We wouldn't use that technique under rivers. We would initially bury it at such a depth, that if the profile permitted, it would go into a material that wouldn't frost heave, or at such a depth that the overburden pressure would inhibit frost heave by the surcharge method. You see, as the frost bulb grows, it is building in its own surcharge. There are other measures available I could expand on as well.

Q Well, I think perhaps once we have more particular information about exactly what studies you've done and what you propose to do, as this material on cross-delta is made available to us we can more intelligently go perhaps a little deeper into some of these techniques.

A Yes, and I assure you,

sir, we will be addressing these problems in the materials.

Q The other question is that in response from questions from Mr. Hollingsworth yesterday morning, I believe Dr. Cooper said that there was no evidence of bed scour in Shallow Bay. Now I understand that on the basis of the route that there are other -- they are crossing other deeper channels in the cross-delta route. Could you tell me if there is any evidence of bed scour in these channels?

WITNESS HOLLINGSHEAD: There are scour holes in some of the other channels.

Q And these would be in the general area of your proposed crossing of these channels?

A How general?

Q Well, you tell me where they are in relation to your crossing and I'll then -- perhaps we can make our own conclusion.

A Several thousands of feet.

Q Is that depth or distance away from the pipe?

A I was thinking of horizontal distance, sir.

Q Well, take a moment then to look at the question of the crossings of water in the context of the dual crossing approach

and I am prepared to hear your comments with respect to the cross-delta route and the crossings of the Mackenzie that are proposed to be on the dual crossing. I understood and I was trying to get the exact reference of it, but I understand the evidence, both on this panel and Panel 1 with respect to the dual crossings is that it's not because of a geo-technical imperative but as a protectorate insurance in the event of any problems developing in the line.

WITNESS CLARK:
A That's right, sir.

Q Now, I'd like to perhaps give you a quote and get your comments on exactly what this means because I'm a bit confused. We have the situation where there doesn't appear to be any geo-technical reason, at least that's the evidence for a dual crossing, but we're going to go through that expense and cost, and I refer you to a report which is not listed as part of this panel but which is part of the list of documents provided by Arctic Gas. This is the report 1974 river breakup and ice study, Mackenzie, Liard and Peel Rivers, a report by Northern Engineering Services Company Limited, actually by T. Blench & Associates, and it's No. 63 on your document list, Mr. Genest. The first part of it is unnumbered but I will read, if I may, the paragraph that I am concerned with. I might say, Mr-Commissioner, that this report was, I understand was in fact done by Dr. Cooper.

WITNESS COOPER: I assisted,

particularly in the review stages and in co-ordinating the whole study, yes.

Q Right, O.K. Well I think as I note here, it's under,the opening is under the letterhead of T. Blench & Associates to Dr. Clark from yourselves, so you perhaps can amplify your involvement in it; but I refer you to the synopsis, the second paragraph which states:

> "The major unresolved problem is the prediction of bed scour that can result from the development and rapid release of a major ice jam. Reliable prediction of scour in such an event is critical to the safe design of the proposed crossing of the Mackenzie River upstream from Point Separation. To solve this problem preliminary work has been carried out on developing a mathematical model of the phenomena and on examining the feasibility of operating the physical laboratory model. If reliable predictions of the magnitude of bed scour associated with severe ice jamming events cannot be developed in time for final design, an alternative solution is to design and construction dual crossings at locations where severe ice jam related scour might occur."

Now, the question may be obvious and also is simple, I gather that what you are saying there is that at this stage an accurate prediction of bed scour problems in the context you've outlined there,is not available.

A At the stage when that report was prepared, the program of analyzing and studying and developing the solutions was at an earlier stage than it is now. Since the time that report was prepared, we have carried it to a much further stage and now have come up with conservative estimates of scour.

Q Now this report was done July of '74. You had no experience with spring run-off with respect to either of these rivers. Would you tell me what additional data about flow, ice jam occurrence or anything else that would be relevant in this prediction has come to your attention since this report was prepared?

A The additional information consists of the results of the analytical study and the study I'm referring to is an on-going one, and just a very preliminary information on that study is contained in that report that you have.

Q Now the report strikes me as saying that -- and I agree with the report, first of all -- that bed scour is unpredictable at the level of knowledge we have, but you can bail out by going with a dual crossing. I understand then that since that time, the additional analytical information you have is sufficient for you to sort of separate yourself from that conclusion.

A I said I believe the way I would have interpreted that statement would be, that if the results of the analyticl study, to which I'm referring, would have been less certain, when they were developed, then yes, that would have been a solution that would have had to be considered.

Q When was the dual crossing proposal put forward by Arctic Gas?

WITNESS HOLLINGSHEAD: the time was about July last year.

Q So the dual crossing proposal in part, besides the insurance that we've discussed, would correspond with this report's recommendation that you can't predict it, therefore go for dual crossings.

A The question of dualling the major crossings seems not to have come over,the reason for dualling seems not to have come over very clearly. The probability of losing a crossing is very remote. I don't think anyone can put a figure on it, but it's my view that it is no greater really than let's say the probability of a break over land. The difference between the two situations is that for an overland break, if you like, you can get at the break and put the line back into service fairly quickly, in a matter of days, let's say. On the other hand, if you had that break occur at a major crossing such as the Mackenzie, at the worst time of year, i.e. just before or during breakup, you would not be able to get at it and repair it for a very significant period of time. That is instead of being out of service for a few days you would be out of service for probably several weeks, or possibly a few months. Therefore in terms of the lost revenue, if you like, or the lost gas, the idea of using a second crossing is indeed cheap insurance. What you are doing is comparing let's say a $10 million crossing with a potential loss of three or $4 million per day by virtue of the lost gas.

Q Dr. Hollingshead, I think that rationale for the crossing -- the dual crossing, has been made quite clear, the economic considerations. What I am suggesting, though, and what I'm enqu iring is how you can say to us that the probability of one of the pipes going out is remote, when your own consultants, one of them is here, says it's a major unresolved problem, is the prediction of bed scour, and if reliable predictions, the magnitude of bed scour associated with severe ice jamming events cannot be developed we have to go to dual crossings. Now they say a reliable prediction is impossible at this stage. Now I've asked what has happened, what has happened since this report that makes you now say the possibility is remote, when in this report it says that it's impossible to make a reliable prediction?

A I thought that Dr. Cooper had spoken on and cleared that up yesterday, but perhaps he'd like to repeat it.

WITNESS COOPER: Well, again and I think I attempted to answer this question a few moments ago. At that point in time, reliable predictions had not been made. Now the development of the analytical model to make these predictions has been under way for one to two years. At this point in time the solutions had not come out of that model at the time of writing of that report, and I think it very clearly states, that unless those solutions were developed and work was being done to develop them, than an alternative design concept would have to be

considered. So the if portion of the statement in that report in my opinion has now been taken out.

THE COMMISSIONER: What was the date of Dr. Blench's report?

MR. ANTHONY: It was prepared as or November '74, but the date on the cover says July '74.

Q Has Dr. Blench collaborated in the development of the analytical models that now you say Dr. Cooper would lead us to believe the passage that has been read from his report ought to be deleted?

WITNESS COOPER:

A Mr. Commissioner, that report was prepared by myself and Mr. Nuttall and a Dr. Mercer, with T. Blench & Associates.

Q That report was completed when?

A It was completed at some point in time in the summer, I believe, of 1974. The writing, at a point in time about July, significant changes weren't made to it, no.

Q You say you and you colleagues wrote that report last July?

A Yes sir.

Q Finished writing it.

A We finished a draft of it which went to N.E.S. for review, etc. The final printing may not have been done until some point later, I'm not sure of the date.

Q Are you telling me that since the time that you wrote that you changed your mind about the passage Mr. Anthony read to you?

A Yes, we've changed our mind and taken that "if" passage out because the work now has been carried out to a stage to enable reliable predictions, although conservative ones, to be made.

Q When did you reach the conclusion that that passage might be deleted?

A Approximately a month ago is when we completed that work.

MR. ANTHONY: Q I understand from the material that has been filed here that Fort Simpson amendment still proposes a dual crossing.

A That's right, sir.

Q So I gather that the reason for it then is solely to deal with the insurance question that we've discussed here?

A That's right, sir.

Q One further question with respect to river crossings. Dr. Hollingshead, I asked you before the session if you would mind reprojecting the slide you presented yesterday, showing the crossing of the Willow Lake River. While you're doing that I can say this is on we were in the middle of the stream looking at the bank.

WITNESS HOLLINGHEAD: Yes sir, we're still in the middle of the stream.

Q Mr. Williams, I wonder

if you could put a light so I could find out what I'm asking? I wonder if you would mind elaborating on that slide by explaining to me, because the figuring is very difficult to read, the amount of excavation and the amount of material that were taken out in that river crossing, and also what material is going back in?

A Well, I haven't actually calculated volumes, but perhaps it will help to give you some of the figures which you probably can't read. The crossing, as I recall, is about seven or 800 feet across. The depth of burial here in mid-channel is probably of the order of 10 feet above the pipe. This depth from the bottom of the pipe to the bottom of the ditch to the top of the bank --

MR. GENEST: Q Is that through the sag point?

A -- that's through the sag point, sorry, this is a cross-section or profile of the right bank, shows the pipe, the solid white line coming beneath the channel and up the bank and that depth is something like 40 feet, 45 feet possibly to the bottom of the pipe.

Q That's at the sag bend again?

A At the sag point, yes. This distance between the sag bend and the over-bend is of the order of 100 feet or so, less than 100 feet, I guess; in the lower sketch, and I might add that

first of all this is a portion of the route that's been re-located so I suppose you might say it's a crossing that's been abandoned. In the second instance it's really a very preliminary cut at the thing and in that sense is simply a schematic, but this lower portion of the drawing shows the section through that sag point, station 29 plus 40.

What it shows is a pipe at the bottom of a ditch which is in the order of 20 feet deep,leaving about a 20 foot depth here and we indicate, what we are attempting to illustrate is that that would not be left open, but that it must be back filled to some depth. It would be filled in. We are looking at a width of cut here in the order of 40 feet. This lower portion, the ditch and the lower portion of this cut is backfilled with native material and to minimize or prevent the erosion, downslope erosion of the finished surface, which is some 30, 40, 50 feet long here, that is blanketed with a select granular material.

Q While you are there then, perhaps, what I am wondering is that we have, looking at the bottom diagram, an area of approximately 20 feet high and 40 feet wide being excavated. Now, could you tell me how far back from the river that excavation is to go?

A From low water level? We are looking at something in the order of 50 feet.

Q So that you end up, at some stage, and I do not want to get into the construction timing of it particularly, but you end up with a 40 by 20 excavation going back about 50 feet.

A Something of that order.

Q Thank you. Perhaps we could take that -- have that available, just in case we want to refer to it, but I would like to have

the lights so that I could look at another part of the problem. That could be shut off.

Now, you have described that crossing technique there and I would like to refer you for a moment so that we could just get another idea of it, to the responses to the Pipeline Application Assessment Group and -- which is exhibit .70 here, and to the question 37, the fold out map which is the last map in that response.

If I can refer you to that last map on response 37, to the schematic diagram -- the upper one on the right-hand side, entitled, "Left Bank Profile".

MR. MARSHALL: Could you give a copy of it to Dr. Clark?

THE COMMISSIONER: What map is that?

MR. ANTHONY: I think it is called section M1, but it is the last fold out map in the response to question 37.

MR. GENEST: We have only got one map.

MR. ANTHONY: WEll, that is right, it is after page 37-4. It is the schematic of the Firth River crossing.

A Yes, sir.

Q And I am referring in particular to the schematic on the lower half of the page, the upper right-hand corner, entitled, "Left Bank Profile."

Without getting into too complicated detail, I wonder if you could interpret that for me by indicating the amount of cutback into the bank that is going to be required there. The depth in the same way that you described in the Willow River crossing and how far back into the bank from the river at below water level.

A Well, to the extent to the point where it comes up to the normal burial depth it is approximately 200 feet.

Q Now, I understand that from your evidence that you propose to excavate these considerable depths -- and I recognize that it is my interpretation of it, and then put in native back fill, which I gather is the material that you have taken out in the excavation --

A That is right, sir.

Q And then put in select backfill which I would -- is that gravel and so on?

A Probably gravel, yes, sir.

Q And that gravel, would that be obtained from the area?

A Yes, sir.

Q The river bed?

A Possibly the active floodplain, but not likely from the river bed itself.

Q What do you do with a backfill that is displaced as a result of this excavation?

A The -- I am sorry, which --?

Q The native backfill that is displaced as a result of the pipe and the replacing it with select backfill. Surface spoil I think is the word you used.

A I think that I prefer to let Mr. Williams speak to that. If he is prepared to.

WITNESS WILLIAMS:

A That material would have to be disposed of in a suitable area that was considered and suitable. In some instances it would go back to a borrow pit. In this case when the borrow pit -- the borrow pit was in fact in the active channel, that would obviously not be acceptable. If the material was not gravel, but a disposal site, an acceptable disposal site would be selected for this material.

Q I notice in that Willow Lake River crossing, there did not appear to be any technique design or any example of disposal site or retaining dike or anything to keep the material from flowing into the river. Does that not form part of the design of the river crossing?

WITNESS HOLLINGSHEAD:

A To keep which material from flowing into the river?

Q Let us put it this way. Assuming that if you dug out the native backfill which

proved to be ice-rich soils and Mr. Williams said well, you dispose of it. I was wondering if there is anything in the design of the river crossing that would incorporate this method?

A I would suspect that that material, any waste material wouldl be placed well back up on the floodplain, but, no, we have not selected waste disposal areas as part of the river crossing design. to this point.

Q Besides the question of finding a suitable dumping area for it, would you not, as part of the river crossing design, also incorporate things like retaining dikes to keep any material from flowing back in? Or is that not a problem that will arise?

A Not necessarily.

Q Well, then perhaps, if we can deal with this in a general way, and you can help my beleaguered now and somewhat troubled mind. We have had evidence in both this panel in which you have said now about the complexity and variety of terrain and the complexity and variety of river crossings that you were to encounter and the geotechnical answer, if I can put it that way, that you have given us, is rather monolithic in the sense that it is a chilled pipeline and it is buried throughout.

Could you tell me whether -- what studies were done in areas of discontinuous permafrost, with the idea of having an unchilled pipeline?

WITNESS CLARK:

A We have an unchilled pipeline in the area of discontinuous permafrost at the southern end.

Q And I am wondering whether you in your consulting role to Arctic Gas were given the task of evaluating, considering, and giving an opinion about the idea of an unchilled pipeline, rather than a chilled one that is being proposed.

A We currently have a program that is going on right now that is dealing with that problem where our line is unchilled. I am not sure that I am answering your question.

QNo, I am wondering whether in the portions that you have indicated in yout application is going to be chilled -- whether you are looking at that --

A I see, if we had looked at that in the context of it being unchilled --

Q Correct --

A No, we have not,sir.

Q Are you presently under-taking studies relating to the question of using an unchilled pipeline rather than a chilled in areas that it is now proposed to go through as a chilled pipeline?

A No, we are not, sir.

Q Now, we have just now looked at the Willow Lake River crossing and the Firth River crossing and what I described as some

rather substantial cuts into the side of the river to accomplish this burial. Could you tell me if as part of your consultative role to Arctic Gas, you examined and studied the possibility of crossing these rivers above ground by either suspension bridge or any other above ground method?

WITNESS HOLLINGSHEAD:

A We have not studied that within N.E.S. directly. There has been a very preliminary study, if you like, of overhead crossings made, yes.

WITNESS HARDY:

A I could perhaps add to that, sir, that it does come within my general function with N.E.S. to at least make suggestions of this kind and in my own personal experience, starting with Trans-Mountain Pipeline and then specifically of more concern is Westcoast, where they do have a series of overhead crossings and we were concerned with the design of those, in fact, we were part of a consortium that took on the actual structural design of the bridge structures in several of them.

Well, I know the general economics of overhead crossings and I know the feeling of the pipeliners, the pipeline operators towards overhead crossings of the type that you have at Flood, you have at Quesnel, you have at Shelley on the Westcoast Transmission line, and I know the pipeliners, the operating pipeliners and generally owners, they have a great reluctance these days to

accept an overhead crossing as a viable alternative to a submarine crossing and on Westcoast, for example, where they are looping their lines, you see, they are going to submarine crossings or the type that we are talking about here, at the very crossings that were originally considered to be economic, more economic for an overhead crossing.

On the Westcoast system there were shorter overhead crossings put in that were not considered to be most economic at that time, they were put in to get some experience with overhead crossings. The experience with overhead crossings is controversial, I will admit, but in my dealings with the operating pipelines, they do not like them, there has to be a major advantage before they will go to them. There are a number of reasons for that. But if I had thought that there were any of these major crossings and I have looked, you see at all of these major rivers that we have been talking about, that there is any place where there is a major advantage is going to the overhead crossing, it would have come within my function to recommend it and I have never run into that case yet.

Q You stated that you were quite familiar with the economics of overhead crossings, and you want to have a major advantage that would result in your recommending a change to the pipeline.

WITNESS HARDY: I don't want to have a major advantage, I am just simply saying that I want to sell the proposition to the owners.

Q Do you mean major economic advantage?

A There has to be some major advantage. Now it usually is economic; in this situation here if we were greatly concerned about the difficulties you're pointing out of getting this excavation up the slope that was projected here a few minutes ago, that might be sufficient reason, you see. But no, the pipeliners, the construction people have not considered that to be the case.

Q Now you haven't -- who do you mean by "the pipeliners" when we're dealing with this application?

A Well, first of all the people concerned with making recommendations on construction within N.E.S. , and my responsibility comes within the N.E.S. organization, and then the people directly representing the potential owners, that's the CAGSL people.

Q I am still somewhat at a loss, if I look at the Willow River or Willow Lake River and the Firth River, I see a fantastic excavation

taking place. Now surely this was brought to the attention of the pipeliners, and my problem is I regard you as pipeliners too, so perhaps you could define it, assist me in that a little bit. But surely that would seem to be a situation where you would want to consider there is a major advantage, for example, and consider the idea of an overhead crossing.

WITNESS CLARK: There's no impediment to the crossing there as planned. The fantastic excavation was I think your term , sir.

WITNESS HOLLINGSHEAD: I would suggest it's nothing like a fantastic excavation.

Q Well, I guess those who build Panama Canals probably don't, but I'm wondering in terms of the en vironmental situation that we are experiencing there, we've heard of these geo-technic problems. Do I understand you, Dr. Hardy, that if you were convinced that either an unchilled pipeline or an overhead crossing had major advantage, that this recommendation would then in the normal course go through the Arctic Gas Pipeliners?

WITNESS HARDY: I would consider it as my responsibility to make the recommendation to either one of the division leaders, such as Dr. Clark here, or to Mr. Dau, and I have discussed overhead crossings with Mr. Dau.

Q. But as I understand the evidence now, is that you're not -- while you're examining the question of how deep and how wide and

where you're going to dump the stuff, you're not examining the question of overhead crossings at these locations.

A I know in generalities that that's not a viable or it's not an attractive substitution for the proposals that you're looking at, in my judgment.

Q Do you know the situation, the sub-surface situation at -- I don't want to deal with this particular example, it was -- I dealt with it because Dr. Hollingshead used it as his example yesterday, I felt it fair to refer to it even though it's been abandoned -

WITNESS HOLLINGSHEAD: If I may add a couple of words, I would suspect that you may get a better answer from the construction people a few weeks down the road, but it would seem to me that -- and we certainly haven't looked at anything like an overhead for the Willow Lake River but I would -- it would be my feeling that they're not even in the same ball park, it's not even close.

WITNESS CLARK: I think the point is we are confident that that bank can be excavated, the pipeline can be placed back in, the backfill can be placed and it will leave a stable bank and one that can be restored; so there's no indication that we should look for something else, that there's no problem to solve, other than executing it, and we're confident it can be done.

Q I'm confident you could

excavate almost anything you wanted. I'm merely trying to get at the question of whether there is an ongoing evaluation to determine not whether you can do it, but whether there's a major advantage other than economic to you doing it a different way.

A Well, there would have to be, to do it a different way there would hae to be an engineering or economic advantage that we haven't seen any impediment in what is there now.

Q So when we're talking in terms of the policy adopted towards this pipeline, you're saying that if we can convince you and we can convince Dr. Hardy that there is an engineering or economic advantage then you may look at an alternative.

WITNESS HARDY: Well, I'm not sure that we do understand the question too clearly, but you're suggesting that we should take every crossing and look at alternative procedures, and what I am trying to say, sir, is that we have looked at the question of overhead crossings in general, and myself in particular, you see, I have seen the practice in the past 20 years, go the very opposite from the way that you're suggesting, that is it's switched over and people are putting in submarine crossings at locations that 20 years ago we thought were almost physically impossible, let alone economically impossible. There have been certain troubles with overhead crossings -- minor ones, mind you, because none of them have fallen down -- but there are certain hazards with

them that the pipeline operators, the maintenance people don't like too well, and this is part of the picture; and what I'm saying is that in discussing this in generalities, the policy I think was adopted by, at least in my own personal discussions with Mr. Dau, that we would stay away or that they would stay away, N.E.S. would stay away from overhead crossings unless there was some major reason that they should be adopted -- it could be economic, it could be physical, it could be environmental, for that matter, or socio-economic, any reason. We do not see and I don't see any reason whatsoever, at this particular crossing, that there should be any time spent on looking at an overhead crossing because of, in generalities we know the answer. It's not going to be acceptable.

Q I gather though that this generalities that you refer to is a basis of your experience that was communicated through to the pipeline consortium, and the decision made really before you did these various on-site studies at the various crossings; is that right?

A Oh yes, my discussions on overhead crossings go back for some time and extend almost on an unofficial basis over a considerable period of time. I was originally in the position that I thought there should be a general study, you see, of possible types of overhead crossings. You see, possible types of crossings where you used the pipe to bridge a shallow ravine or a narrow ravine, and that sort of thing, and these have been

looked at, at least that's my understanding. I haven't followed them up to the final conclusion to see why they were not adopted, but they have been given consideration.

Q You would agree -- and I want to address this to Dr. Hardy -- you would agree that there are certain situations where in fact you would be better off with overhead crossings than subterrain crossing?

A On this line? No, I don't agree.

Q Well, in generalities.

A Well, this becomes very -- you see, the trouble is, sir, that there's no exact answer to these problems. The same as there is no one precise exact answer to exactly where a pipeline should be located, you see, and the location evolves finally and the sort of thing that you're talking about, you see, is the sort of thing that people in the business you see, will sit around until the small hours of the morning discussing, you see, and arguing on the relative merits of overhead crossings as compared to submarine crossings. I could produce people here that would agree with you 100% that all these are wrong, they should have nothing but overhead crossings; but then they're structural designers too, they're not geotechnical people.

All that I can say is that in my best judgment these people have gone the right way and it is within the experience I have seen as to

the way the operating people under the circumstances most dosely analagous to what we're going to have on this line, the way they have been going in their experience over the past 20 years.

Q I think I now understand the situation, but can I have the same sort of considerations discussed with respect to the chilled line, because here you're not following the existing generalities but you've in fact launched off on your own.

A The chilled line, of course, came up very early in the discussions of natural gas lines, you see, and in the original discussions the thing was that many people, including quite competent experts in the field, thought that going to a chilled line solved all the problems that they had visualized for the hot oil line. There was no problem left, you see, but it took only a very few hours of discussion to show that this was not so and that the ramifications of these things, on a project of this size, you see, are such that, well it's like having a leaky pail, you plug up one hole and you say, we will get rid of that hole by using a cold line," but you'll find that another hole opens up somewhere else, and so it's not a simple decision to say that by using the chilled line, that that solves all your problems, you haven't got any problems left, and all sorts of new problems come up.

Now the basic problem of the

geotechnical problem, looking at the geotechnical aspects of the problem are pretty simple, it is very attractive. There is a problem exactly where you cut it off; but then the cut-off point is only partially a geotechnical problem. Now the other thing, I'm not prepared to get into that, perhaps Mr. Williams could, there are other people in the N.E.S. organization, the CAGSL organization that could discuss that in detail; but I don't care, you see, as a geotechnical expert on this thing, whether they cut the chilled line off at Fort Simpson or whether it's north of there or south of there by several hundred miles, we can accommodate it geotechnically.

Q My consideration on this point, of course, is that I am just impressed at the variety of problems, the number of holes in the pail, Dr. Hardy, the variety of terrain, the variety of problems, the variety of river crossings, and yet the one answer to everything is the chilled frozen pipeline. Now that's what troubles me, and that's what I would think that as a geotechnical advisor you would perhaps be able to explain.

A That is a basic decision that has to be made and was made very early in the discussions. We will go to a chilled line

But then there are many,the details of that, you see, require a great deal of study. Only one of the aspects is concerned with the geotechnical situation.

Q Now, you said that the major factors would have to determine any change, for example of going overhead or going above ground across an area or not chilling in an area and I would understand that if I could give you a major environmental reason for doing so, that would be a legitimate consideration in the type of advice that you are involved in?

A I would say this, sir, that we could build an overhead crossing, you see. It can be built.

Q You are not studying the possibility right now, but if I could convince you that you should , you might be prepared to do that --

A We could build it, yes.

Q You could probably build some very good lines with some overheads and some undergrounds and so on --?

A What I am telling you, sir, is there just is no reason that I am aware of that would justify me, for example, making recommendation to N.E.S. and CAGSL that they should start

looking at overhead crossings. That is up until right now.

Q Perhaps over the next weeks and months we may be able to give you some reasons. That is all the questions that I have.

MR. SCOTT: Mr. Commissioner, it is one o'clock.

THE COMMISSIONER: Yes, well then, we will adjourn until 9 o'clock tomorrow morning.

(PROCEEDINGS ADJOURNED TO MARCH 21, 1975.)